

# **Groundwater Monitoring Plan for Defense Reutilization and Marketing Office**

**Naval Submarine Base  
New London  
Groton, Connecticut**



**Northern Division  
Naval Facilities Engineering Command**

**Contract Number N62472-90-D-1298**

**Contract Task Order 0267**

**February 1998**



**Brown & Root Environmental**

A Division of Halliburton NUS Corporation

**GROUNDWATER MONITORING PLAN  
FOR  
DEFENSE REUTILIZATION AND MARKETING OFFICE**

**NAVAL SUBMARINE BASE - NEW LONDON  
GROTON, CONNECTICUT**

**COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT**


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## **1.0 INTRODUCTION**

This Groundwater Monitoring Plan for the Defense Reutilization and Marketing Office (DRMO) at the Naval Submarine Base New London (NSB-NLON) in Groton, Connecticut was prepared for the U.S. Department of the Navy (Navy) by Brown & Root Environmental (B&R Environmental) under the Comprehensive Long-Term Environmental Action Navy (CLEAN), Contract Number N62472-90-D-1298, Contract Task Order (CTO) 0267.

This document has been prepared in accordance with the Navy Installation Restoration Laboratory Quality Assurance Guide (Interim Guidance) of the Naval Facilities Engineering Service Center, (NFESC, Feb. 1996).

### **1.1 SCOPE AND OBJECTIVES**

Due to elevated levels of lead, Polychlorinated Biphenyls (PCBs), and Polycyclic Aromatic Hydrocarbons (PAHs) in the soil at the DRMO, a Time-Critical Removal Action was performed by OHM Remediation Services Corporation during the course of the Phase II Remedial Investigation (B&R Environmental, March 1997). After removal of contaminated soil from the northern half of the site, a cap was installed to reduce precipitation infiltration and leaching of contaminants to the groundwater. The objective of this Groundwater Monitoring Plan is to provide the approach for long-term monitoring to evaluate the effectiveness of the cap and to confirm that contamination is not migrating through the soil, into the groundwater, and ultimately discharging to the Thames River. This groundwater monitoring is part of the post-closure associated with the DRMO cap.

To meet this objective, seven existing Phase I and Phase II monitoring wells and three newly installed monitoring wells will be sampled for a suite of analytes based on an evaluation of site history and previous analytical results. Upon evaluation of the first year of quarterly analytical results (4 rounds), and subsequent to the planned second year of sampling, the frequency of sampling events and the suite of analytes may be adjusted.

### **1.2 APPROACH**

Five existing monitoring wells, which were installed as part of the Phase I and Phase II investigations, and two newly installed monitoring wells will be used to monitor the groundwater prior to discharge into the Thames River. Two existing and one new monitoring well, to be installed immediately upgradient of the site, will be used to establish the quality of groundwater flowing through the capped area of the DRMO

site. This monitoring effort will be conducted to verify that significant contamination is not leaching to the groundwater from the capped area at concentrations above regulatory criteria and impacting the Thames River. The following groundwater monitoring approach is proposed for the DRMO:

- (1) Conduct groundwater monitoring at ten monitoring wells. Three of these wells will be newly installed wells, including one upgradient well (6MW9S) and two downgradient wells (6MW10S and 6MW10D) along the perimeter of the facility. The remaining seven wells will be existing wells, including the five downgradient wells located along the perimeter of the facility (6MW1S, 6MW2S, 6MW2D, 6MW3S, and 6MW3D), and the two upgradient wells located to the east of the site (6MW6S and 6MW6D). These wells will be screened to monitor shallow and deep groundwater in the overburden. The upgradient wells will establish groundwater concentrations upgradient of the DRMO cap. The downgradient wells will be used to monitor groundwater leaving the site.
- (2) The monitoring program will be revised yearly based on analytical data collected from previous sampling events. It is the intent of the Navy to conduct sampling and analyses only as necessary. Therefore, once baseline conditions are established after the first year of sampling (4 rounds of data), analytes that are not expected and not detected will be deleted from the analytical program for subsequent sample events. It is currently anticipated that sampling will be performed on a quarterly basis for the first year of monitoring and twice a year for an additional two years.
- (3) Water-level measurements will occur during each sampling round for the ten wells. Data for both high tide and low tide will be collected. In addition, pH, specific conductance, salinity, turbidity, temperature, oxidation reduction potential (Eh) will be measured.
- (4) Groundwater monitoring samples will be collected only at periods of low tide to ensure the hydraulic gradient is discharging to the Thames River.

### **1.3 REPORT ORGANIZATION**

This plan has been prepared in the following format to address the requirements for long-term groundwater monitoring at the DRMO. Section 1.0 of the plan is this brief introduction including the project scope, objectives, and approach. Section 2.0 presents a background summary of the use and previous investigations for the DRMO. Section 3.0 provides the requirements for installation of the monitoring wells and pumps. Section 4.0 discusses the sampling and analysis requirements. Section 5.0 provides the criteria for data evaluation and recommendations for future monitoring.

## **2.0 DRMO BACKGROUND AND SETTING**

This section provides a background and setting, as well as, a summary of previous investigations at the DRMO site. Section 2.1 provides a brief site description. The previous sampling and analytical history is summarized in Section 2.2 and Section 2.3 discusses site physical features.

### **2.1 SITE DESCRIPTION**

The DRMO is adjacent to the Thames River in the northwestern section of NSB-NLON. In the past, the southern half of the DRMO was covered with asphalt, most of which was deteriorated, while the northern portion was unpaved and had a gravel surface. The site was subsequently remediated in 1995 and a composite cap was placed over a majority of the central and northern portions of the site (OHM, September 1995). Bituminous concrete pavement was then placed over the entire area of the composite cap. The DRMO is the storage and collection facility for items to be sold at auctions and sales held periodically throughout the year. Figure 2-1 displays the location of NSB-NLON. Figure 2-2 shows the site location within NSB-NLON, and Figure 2-3 shows the general site plan.

The DRMO was used as a major base landfill and burning ground from 1950 to 1969. The materials burned and landfilled included construction materials, combustible scrap, and other non-salvageable waste items. These materials were burned on the Thames River shoreline adjacent to the current location of the DRMO. The residue was pushed to the shoreline and partially covered.

Atlantic Environmental Service, Inc. (Atlantic) personnel reviewed archived aerial photographs of the DRMO area. The 1934 photographs show fill in the southern portion of the site. Fill for bulkheads and docks south of the DRMO did not exist at that time. Aerial photographs from 1951 show the land in its present configuration, except for the northwest portion which was not filled at that time.

Atlantic personnel inspected the site on September 30, 1988. Metal and wood products were stored throughout most of the site. Buildings 479 and 355 are located within the paved area to the south and are primarily used for storage. Building 491, located in the unpaved area to the north, is used for miscellaneous storage, including batteries. Metal baling operations are performed adjacent to Building 491 on a gravel surface. Based on an inspection of the building plans, Atlantic personnel identified the presence of a former battery acid handling facility at the north section of the site, within Building 491. A large scrap yard is located north of Building 479. Submarine batteries were stored in the

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**LOCATION MAP  
NSB - NEW LONDON  
GROTON, CONNECTICUT**

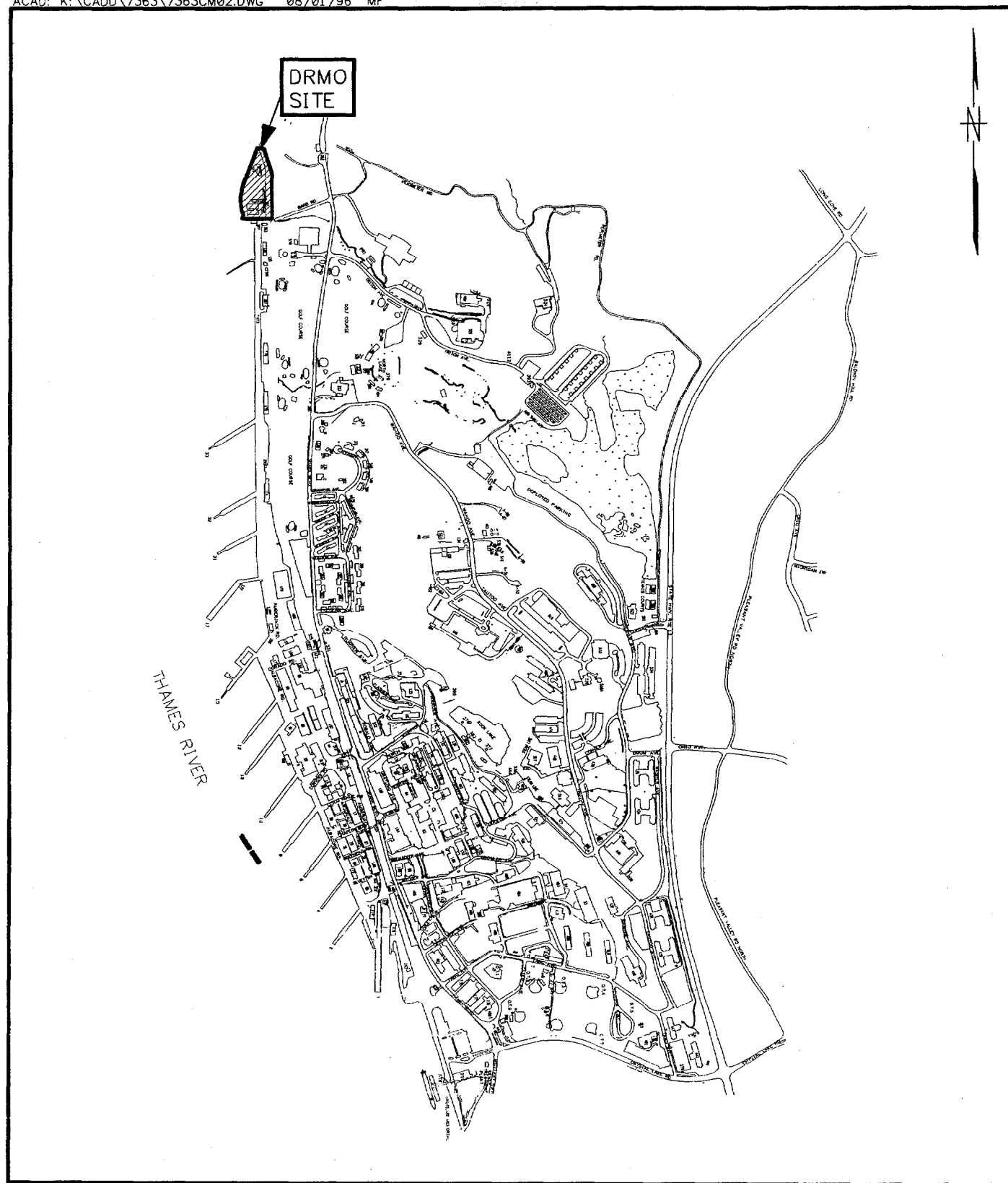
**FIGURE 2-1**

2000 0 2000 4000 Feet

  
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01508018





DRMO LOCATION MAP  
NSB — NEW LONDON  
GROTON, CT

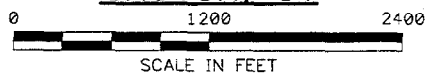
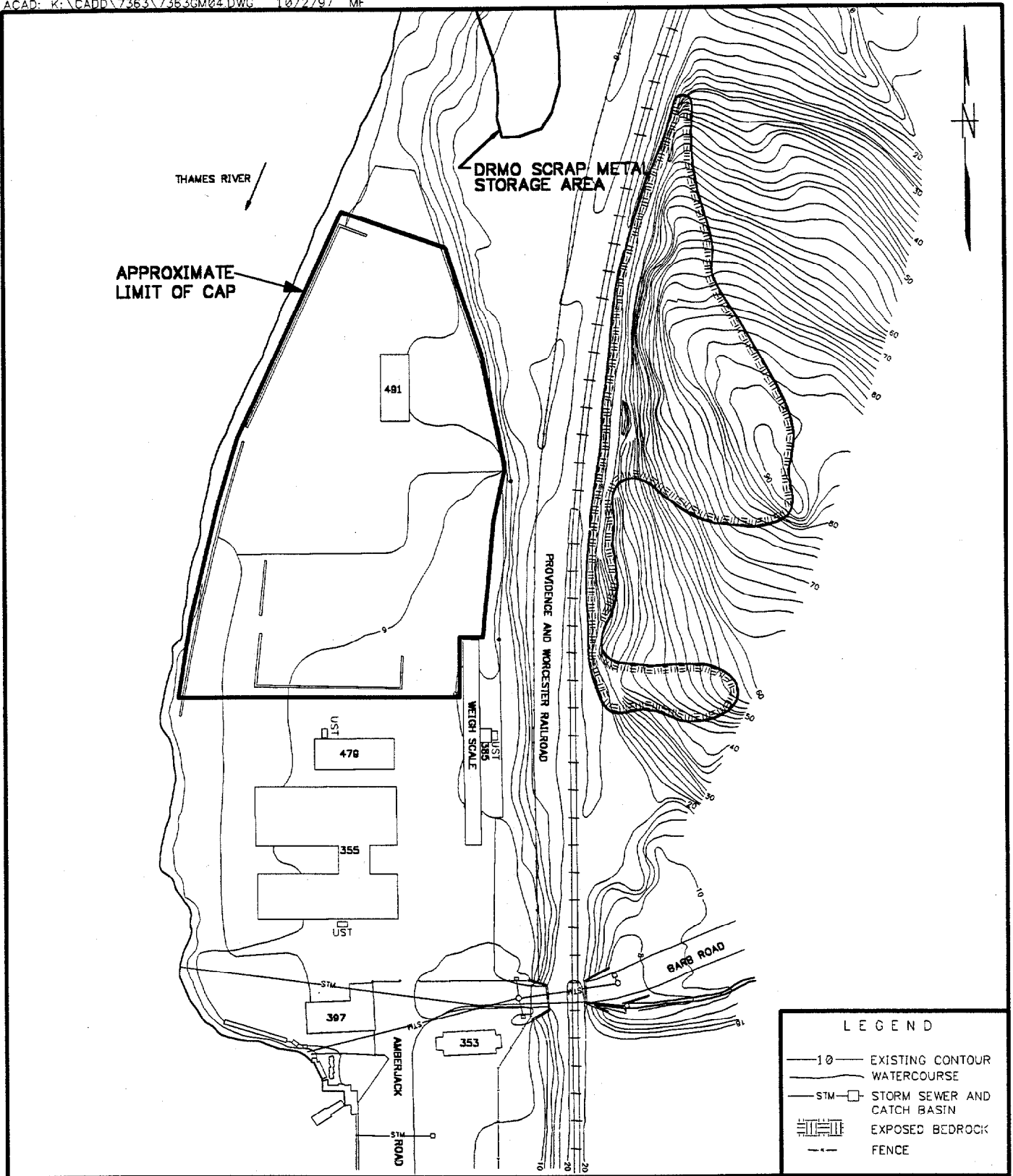


FIGURE 2-2



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**DRMO SITE PLAN**  
**NSB - NEW LONDON**  
**GROTON, CT**

0 100 200  
 SCALE IN FEET

**FIGURE 2-3**

  
**Brown & Root Environmental**



southeast portion of the site adjacent to the railroad tracks; no leakage was observed. An in-ground rubber-lined tank and associated pumping facilities were noted on the plans. DRMO personnel indicated that the tank actually may have been installed directly adjacent to the building to the east.

A Time-Critical Removal Action was performed at the DRMO by OHM Remediation Services Corporation. Construction aspects of the removal action were completed in January 1995. The removal action focused on the removal of soil contaminated with lead, PAHs, and PCBs from the northern half of the DRMO.

The excavated area was backfilled with clean borrow material from an offsite location. The cap consisted of a woven geotextile liner, a geosynthetic clay liner (GCL), and a nonwoven geotextile liner. The spent acid tank was also removed.

## **2.2 PREVIOUS INVESTIGATIONS**

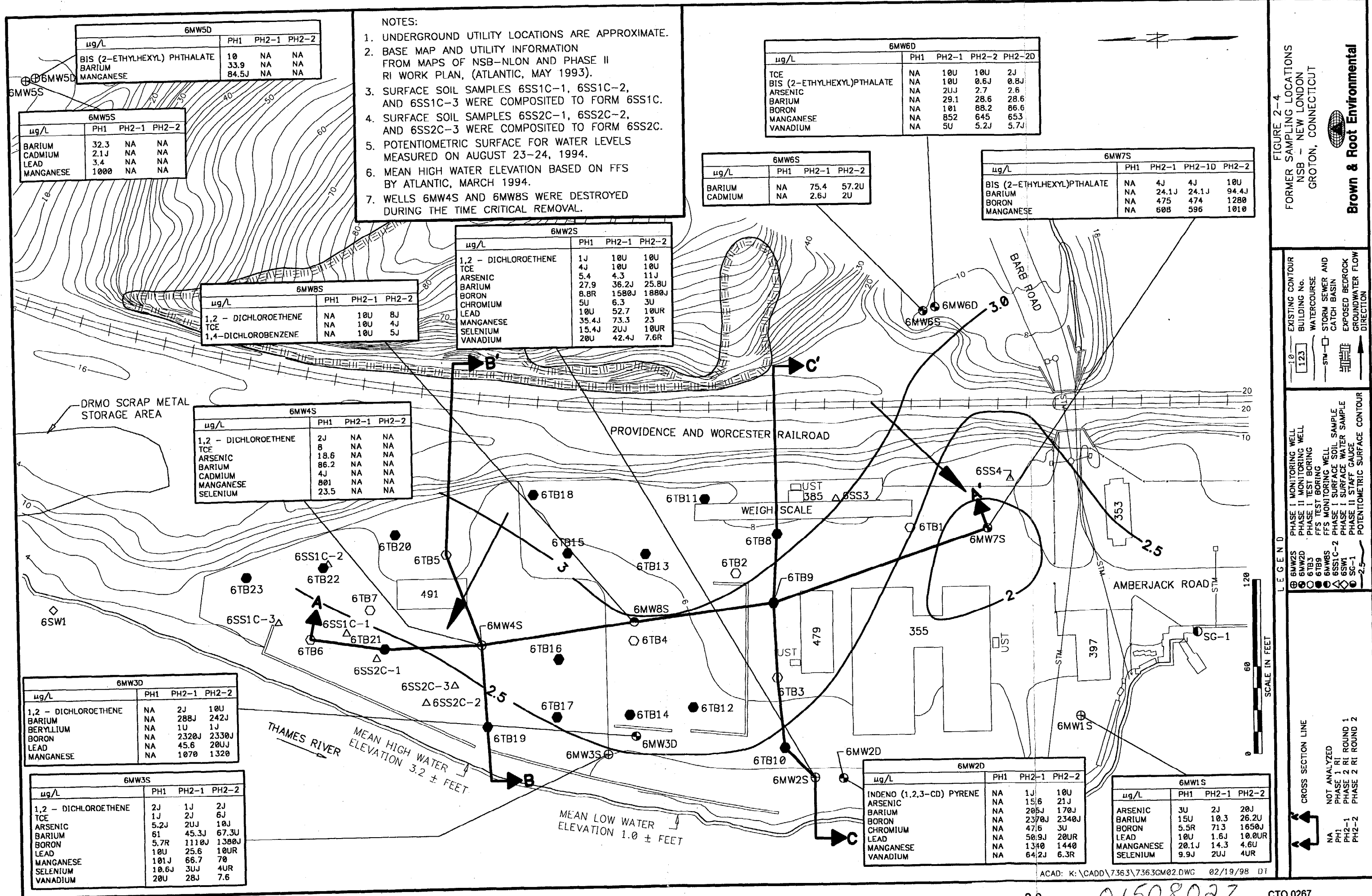
### **2.2.1 Phase I RI**

The Phase I RI at this site included test borings and monitoring well installation, as well as, soil, surface water, and groundwater sampling. Twelve shallow subsurface (less than 2 feet deep) soil samples plus one field duplicate and 12 subsurface (greater than 2 feet deep) soil samples plus one field duplicate were collected from seven test borings and five monitoring well borings. Four surface soil samples (two composite and two grab samples) plus one field duplicate were collected and analyzed. Six groundwater samples plus one field duplicate were collected from five shallow wells and one deep well. Additionally, one surface water sample was collected from the Thames River at the north end of this site (B&R Environmental, March 1997). Refer to Figure 2-4 for sample locations and a summary of analytical results.

Some evidence of the former landfill was encountered during the drilling, including wood fragments, brick, metal, but predominately earth fill material. The depth of the fill varied from zero to eight feet. (Atlantic, August 1992)

Concentrations of Volatile Organic Compounds (VOCs) in the soil were generally low. However, the following VOCs were found in 6TB4 (6-8 feet): vinyl chloride detected at 1,300 micrograms per kilogram ( $\mu\text{g/kg}$ ), trichloroethene detected at 20,000  $\mu\text{g/kg}$ , and tetrachloroethene detected at 210  $\mu\text{g/kg}$ . Semi Volatile Organic Compounds (SVOCs) were present in most soil samples collected in the former landfill area. They were predominately comprised of PAHs, many of which were detected at elevated levels (maximum of 931,000  $\mu\text{g/kg}$ ). A PCB, Aroclor 1260, was detected at almost all soil sample locations with

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concentrations ranging from 52 µg/kg to 12,000 µg/kg. Pesticides were detected in one soil sample at elevated concentrations. The total pesticide concentration was 57,800 µg/kg, consisting of DDT, DDD, and DDE.

Out of the 24 soil samples analyzed for Toxicity Characteristics Leaching Procedure (TCLP) metals, 21 contained one or more metals exceeding "To Be Considered" values (TBCs). Metals exceeded TBCs for barium, cadmium, chromium, lead, mercury and silver. TCLP values for lead ranged from 6.2 to 52 milligrams per liter (mg/L) at three locations (Atlantic, August 1992), which exceeded the hazardous waste characteristic value of 5 mg/L.

Trichloroethene and 1,2-dichloroethene were present in three downgradient wells (6MW2S, 6MW3S, and 6MW4S). No SVOCs (including PAHs), pesticides, petroleum hydrocarbons, or PCBs were detected in any wells at the DRMO site. Low levels of phthalates and benzoic acid were detected in the upgradient well 6MW5D. The inorganic groundwater analysis results indicated that selenium exceeded the primary drinking water standards at wells 6MW2S, 6MW3S, AND 6MW4S (Atlantic, August 1992).

No VOCs, SVOCs, pesticides, or PCBs were detected in the upgradient surface water sample. Comparison of the inorganic results for this sample with the downgradient water sample (Goss Cove) did not suggest any detectable impact on the Thames River from NSB-NLON based on this limited data set (Atlantic, August 1992).

#### **2.2.2     Draft Focused Feasibility Study Field Investigation**

A field investigation in support of the Draft Focused Feasibility Study (FFS) was performed at the DRMO site in October 1993 to better define the extent of soil contamination. Split-spoon samples were collected from 17 borings. Refer to Figure 2-4 for sample locations and a summary of analytical results. One or more samples were collected from each boring based on visual evidence of contamination, field-measured organic vapor readings, and field-measured lead contamination (using X-Ray Fluorescence). Twelve surface (less than 2 feet deep) soil samples and twelve subsurface (greater than 2 feet deep) soil samples were collected. One surface and two subsurface field duplicates were also collected. One of the borings was completed as a monitoring well (B&R Environmental, March 1997).

The soil borings indicated the depth of fill ranged from approximately 1.5 to 20 feet. Fill material consisted of wood, glass and metal scrap, in a predominately sand and gravel matrix (Atlantic, March 1994).

The highest concentrations of VOCs were present in soil samples 6TB17, 6TB19, and 6TB16 where values ranged from 9,600 to 4,840 µg/kg for total VOCs. The TBC value was exceeded for trichloroethene at two locations where values were reported at 3,900 and 40 µg/kg. The TBC value for 1,2-dichloroethane was exceeded at 6TB20 (79 µg/kg) and toluene at 6TB19 (2,900 µg/kg). SVOCs, predominately PAHs with concentrations ranging from non-detected to 931,000 µg/kg, were detected in soil across the site. PCBs (Aroclor 1254, Aroclor 1260, and Aroclor 1242) were detected at nearly all boring locations at low to high concentrations, ranging from 76 to 34,700 µg/kg. Pesticides (DDE, DDD, DDT) were detected at many locations across the site, primarily at low concentrations; however, several locations were found to have elevated levels. Inorganic compounds levels were above background at all locations. Of primary concern at the site, were the levels of lead which ranged from 5.7 to 12,400 µg/kg.

Two soil samples were collected and analyzed for full TCLP parameters. There were no SVOCs, pesticides, or PCB values above the Connecticut Department of Environmental Protection (CTDEP) TBC values. Cadmium and 1,2-dichloroethane were detected in one sample above TCLP TBC values at concentrations of 0.028 and 10 micrograms per liter (µg/L), respectively. Both samples contained lead above the TCLP TBC value at concentrations of 904 and 525 µg/L (Atlantic, March 1994).

### **2.2.3      Phase II RI**

Five new groundwater monitoring wells (two shallow and three deep) were installed and sampled during the Phase II RI. Additionally, four previously installed shallow wells were sampled. Two rounds of groundwater sampling were completed and ten samples (including one field duplicate sample) were collected during each sampling round. Three subsurface soil samples were collected during the installation of three of the new wells (B&R Environmental, March 1997). Refer to Figure 2-4 for sample locations and a summary of analytical results.

Relatively high concentrations of multiple organic and inorganic compounds were detected in the soil matrix at the DRMO. Organic chemicals detected at high concentrations include various halogenated aliphatic compounds, PAHs, phthalate esters, Aroclor-1254, and Aroclor-1260. The maximum observed concentration of the water insoluble organic compounds in groundwater was bis(2-ethylhexyl)phthalate at 20 µg/L (B&R Environmental, March 1997).

In spite of the fact that relatively high concentrations of some VOCs were detected in the subsurface soil, it does not appear that substantial impact on the groundwater has occurred to date. For example, although halogenated organic compounds such as 1,2-dichloroethene and trichloroethene were detected in soil samples at concentrations ranging to 16,000 µg/kg and 7,100 µg/kg, respectively, no evidence of

substantial impact on groundwater quality has been noted. The maximum concentration of a halogenated organic compound in groundwater samples was 8 µg/L (1,2-dichloroethene and trichloroethene) (B&R Environmental, March 1997).

In addition to the various organic chemicals detected in soil at the DRMO, relatively high concentrations of lead still remained in soil after the Time-Critical Removal Action was conducted. Surface and subsurface soil concentrations of lead ranged as high as 4,980 mg/kg and 2,140 mg/kg, respectively. In spite of the high lead concentrations in soil, only limited evidence of lead migration to the water table is evidenced by the groundwater analytical results. Although lead was detected as high as 52.7 µg/L in one unfiltered sample, lead concentrations in filtered groundwater samples ranged no higher than 2.4 µg/L. Furthermore, the cap will effectively minimize precipitation infiltration to the groundwater (B&R Environmental, March 1997).

#### **2.2.4 Time-Critical Removal Action**

A Time-Critical Removal Action was performed at the DRMO by OHM Remediation Services Corporation during the course of the Phase II RI. Construction aspects of the removal action were completed in January 1995. The removal action focused on the removal of soil contaminated with lead, PAHs, and PCBs from the northern half of the DRMO. A total of 73 soil samples (plus 6 field duplicates) and two pavement samples were collected from the scrap yard area north of Building 479.

Twenty-three individual soil samples (i.e., samples 16144-1 through -18 and -21 through -25) plus 2 field duplicates and 5 composite samples (i.e., samples 16144-26, -27, -30 through -32) were collected from 25 locations prior to excavation to better define the limits of PCB-contaminated soil (Figure 2-5). In addition, pavement cores (samples 16144-33 and -34) were taken from two borings (16144-19 and -20). Materials were then excavated based on data from these and previously-collected samples and initial excavation areas were determined based on the following revised preliminary remediation goals (PRGs):

Lead:	500 mg/kg
PCBs:	10 mg/kg
Carcinogenic PAHs:	100 mg/kg

Initial activities at the site included pre-excavation sampling and analysis focused on better defining the limits of PCB-contaminated soil in the areas to be excavated. Analytical results for the pre-excavation sampling are provided in Table 2-1. Composite samples were also collected and analyzed using TCLP for waste profiling. Results of the TCLP analysis for metals are provided in Table 2-2. Soil was excavated to

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- NOTES:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
  2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON AND PHASE II RI WORK PLAN, (ATLANTIC, MAY 1993).
  3. SAMPLE LOCATIONS ARE APPROXIMATE AND WERE TAKEN FROM INTERIM REMEDIAL ACTION REPORT (OHM, SEPTEMBER 1995).
  4. SAMPLES 57-59 WERE SAMPLED AFTER THE PRE-EXCAVATION SAMPLES, BUT WERE SUBSEQUENTLY EXCAVATED.

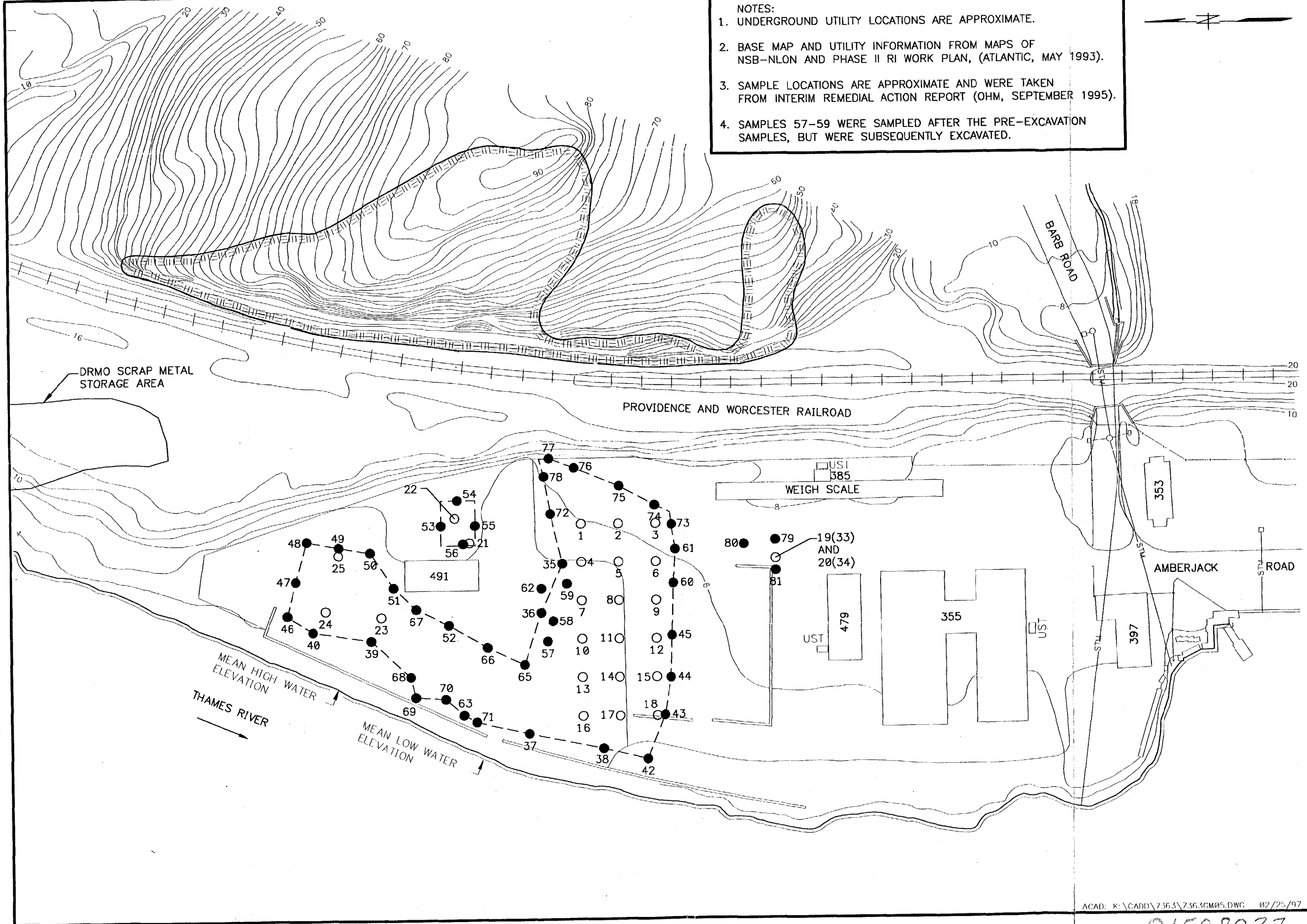


FIGURE 2-5  
TIME-CRITICAL REMOVAL  
NSB - NEW LONDON  
GROTON, CONNECTICUT

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LEGEND

EXISTING CONTOUR  
BUILDING No.  
123

WATERCOURSE  
STW-□  
STORM SEWER AND  
CATCH BASIN

EXPOSED BEDROCK

POST-EXCAVATION SOIL SAMPLE  
PRE-EXCAVATION SOIL SAMPLE  
LIMIT OF EXCAVATION

● 60  
○ 6

ACAD: K:\CADD\7363\7363CM05.DWG 02/25/97 111

2-15

01508032

CTO 0267

089605/P



TABLE 2-1

**PRE-EXCAVATION GRID SAMPLING RESULTS  
TIME-CRITICAL REMOVAL ACTION  
DRMO, NSB-NLON, GROTON, CONNECTICUT**

Sample Number	Total Solids (%)	Total PCBs (µg/kg)	PCBs (µg/kg)		
			Aroclor 1248	Aroclor 1254	Aroclor 1260
001	93.1	3,330	ND	1,100	2,230
002	96.1	443	ND	284	159 J
003	97.8	258	ND	ND	258
004	95.1	12,440	330	3,760	8,350
005	93.5	--	--	--	--
006	94.3	9,621	221	2,920	6,480
007	93.5	2,013	366	889	758
008	96.5	7,429	339	1,910	5,180
009	94.9	--	--	--	--
010	91.6	9,806	296	3,020	6,490
011	92.8	18,130	1,450	9,840	6,840
012	95.5	ND	ND	ND	ND
013	91.7	121,260	9,760	77,100	34,400
014	91.2	71,180	3,880	39,900	27,400
015	93.5	ND	ND	ND	ND
016	89.4	--	--	--	--
017	92.4	37,780	2,180	18,100	17,500
018	95.5	ND	ND	ND	ND
021	95.9	3,468	1,860	1,190	418
022	94.8	691	ND	328	363
023	96.2	394	ND	152 J	242
024	95.8	827	119 J	395	313
025	96.3	198	ND	117 J	80.6 J
028	96.4	520	ND	224	296
029	96.2	632	96.2 J	334	202

Reference: OHM Corporation, September 1995.

**NOTES:**

ND        Compound was not detected above method detection limit.  
 --        Sample not analyzed for this parameter  
 J        Estimated value.

**TABLE 2-2**  
**TCLP METAL RESULTS**  
**TIME-CRITICAL REMOVAL ACTION**  
**DRMO, NSB-NLON, GROTON, CONNECTICUT**

<b>SAMPLE</b>	<b>026</b>	<b>027</b>	<b>030</b>	<b>031</b>	<b>032</b>
<b>DATE</b>	<b>09/15/94</b>	<b>09/15/94</b>	<b>09/15/94</b>	<b>09/15/94</b>	<b>09/15/94</b>

**Metals (mg/L):**

<b>Arsenic</b>	<b>0.002 J</b>	<b>0.001 J</b>	<b>ND</b>	<b>0.013</b>	<b>ND</b>
<b>Barium</b>	<b>1.05</b>	<b>0.981</b>	<b>0.619</b>	<b>0.501</b>	<b>0.693</b>
<b>Cadmium</b>	<b>0.158</b>	<b>0.18</b>	<b>0.031</b>	<b>0.03</b>	<b>0.023</b>
<b>Chromium</b>	<b>0.01</b>	<b>0.005 J</b>	<b>0.004 J</b>	<b>0.006 J</b>	<b>0.008</b>
<b>Lead</b>	<b>11.9</b>	<b>5.35</b>	<b>1.73</b>	<b>23.6</b>	<b>1.25</b>
<b>Mercury</b>	<b>ND</b>	<b>ND</b>	<b>ND</b>	<b>ND</b>	<b>ND</b>
<b>Selenium</b>	<b>0.002 J</b>	<b>ND</b>	<b>0.005 J</b>	<b>ND</b>	<b>ND</b>
<b>Silver</b>	<b>ND</b>	<b>ND</b>	<b>0.003 J</b>	<b>0.0008 J</b>	<b>ND</b>

Reference: OHM, September 1995.

**NOTES:**

ND                      Compound was not detected above method detection limits.  
J                         Estimated value outside method detection limits.

a depth of approximately 3 feet (or to the water table if the depth to water was less than 3 feet). Approximately 4,700 tons of soil were removed.

Confirmation sampling was initiated when excavation operations were approximately 75% complete. Forty-five confirmation soil samples plus four field duplicates (i.e., samples 16144-35 through -82) were collected from the sidewalls of the excavation area (Figure 2-5). Some further excavation was subsequently performed. Residual contamination above the PRGs remained in the soil after excavation was complete due to the excavation being limited to 3 feet by the shallow water table and exceedances of the allotted time for the project (B&R Environmental, March 1997). Table 2-3 provides the post-excavation sampling results and Figure 2-5 shows the limits of the excavation.

After the completion of removal activities, the area was backfilled with clean borrow material. A cap consisting of a woven geotextile liner, a geosynthetic clay liner (GCL), and a nonwoven geotextile liner was installed. Approximately 12 inches of crushed stone and 3 inches of asphalt were placed over the clay/geotextile cover. The remaining (paved) portion of the DRMO was also upgraded via placement of an asphalt layer.

## **2.3 PHYSICAL CHARACTERISTICS**

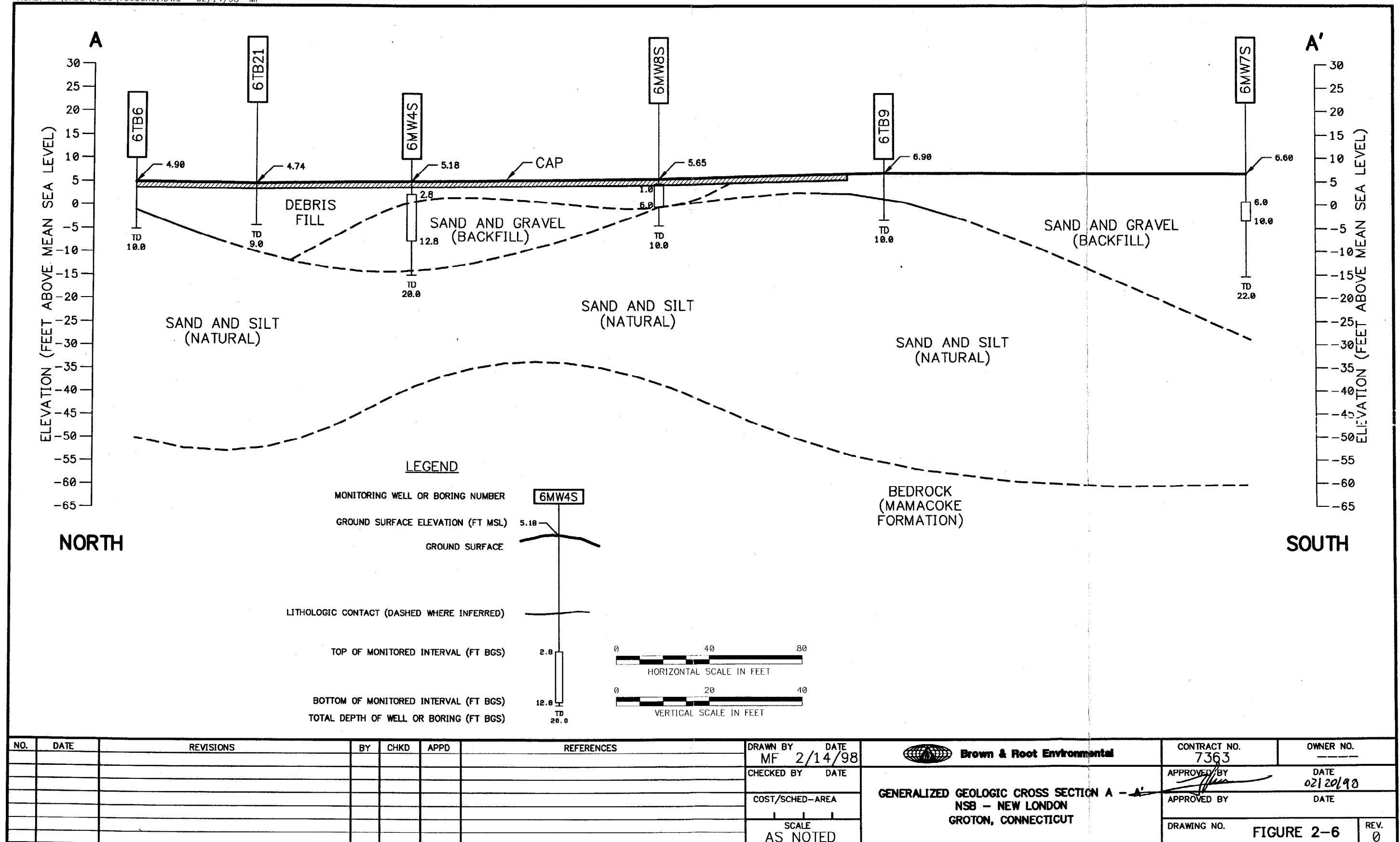
This section presents a summary of physical characteristics for the DRMO based on information generated during the Phase I and Phase II RIs. Topography and surface features, surface water, soil, geology, and hydrogeology are discussed in the subsections that follow. Figure 2-4 shows the topography of the DRMO. Figures 2-6 and 2-7 show bedrock and bottom-of-fill topography respectively. Figures 2-8, 2-9, and 2-10 show stratigraphy and lithology cross-sections for this site.

### **2.3.1 Topography and Surface Features**

To the east of the DRMO, there is an exposed bedrock high that slopes steeply to the west towards the site. Across the railroad tracks shown on Figure 2-4, the ground surface continues to slope to the west, to an elevation of 10 feet msl. The ground surface at the DRMO itself gently slopes to the west from an elevation of 8 feet msl along the eastern boundary of the site to 4 feet msl at the Thames River. The land is relatively flat, low lying and prone to flooding by the Thames River (B&R Environmental, March 1997).

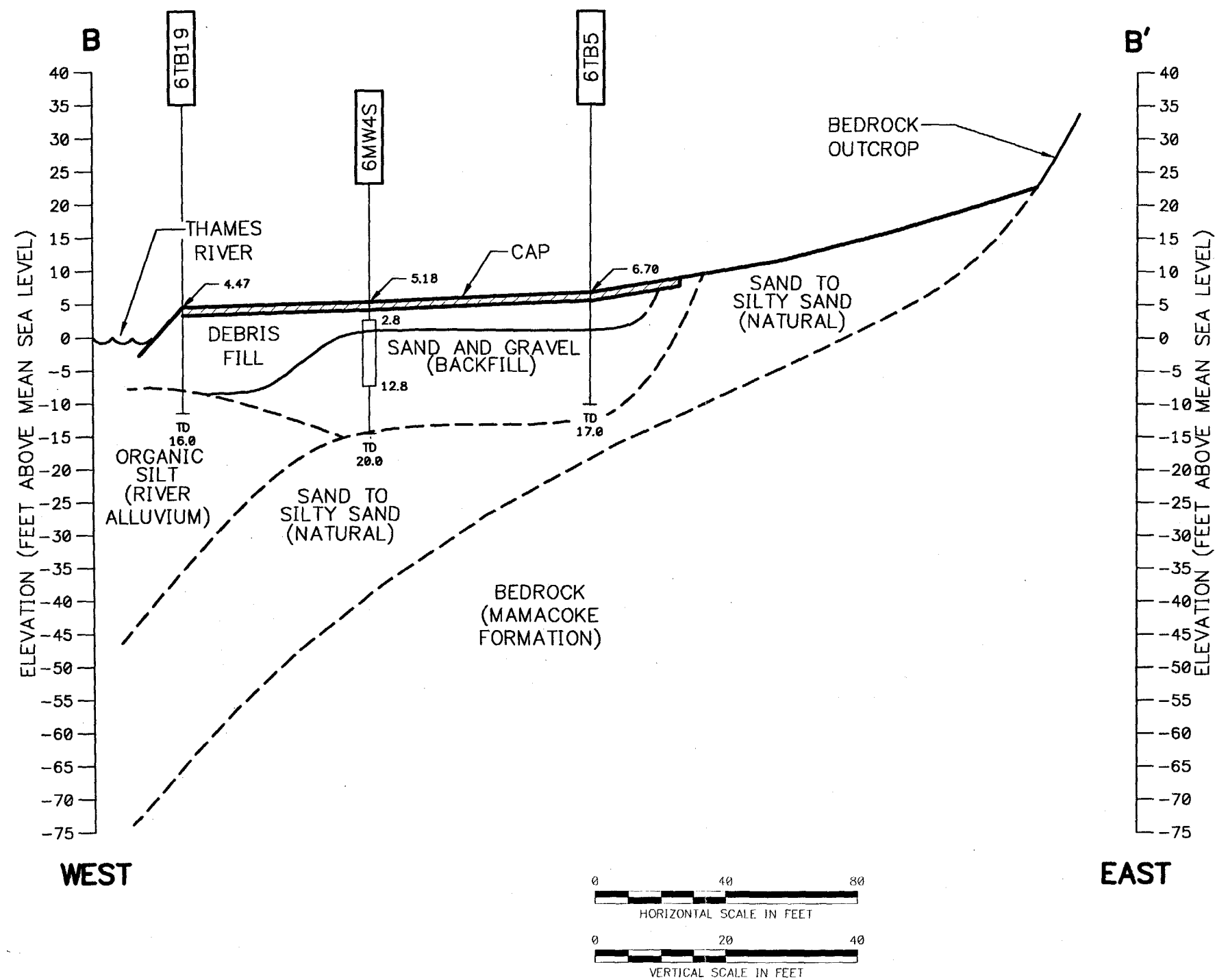
A cap was installed during the Time-Critical Removal Action and this area, as well as the remaining portion of the DRMO, was upgraded via placement of an asphalt layer. Buildings 479, 355 and 491 are located within the paved area.

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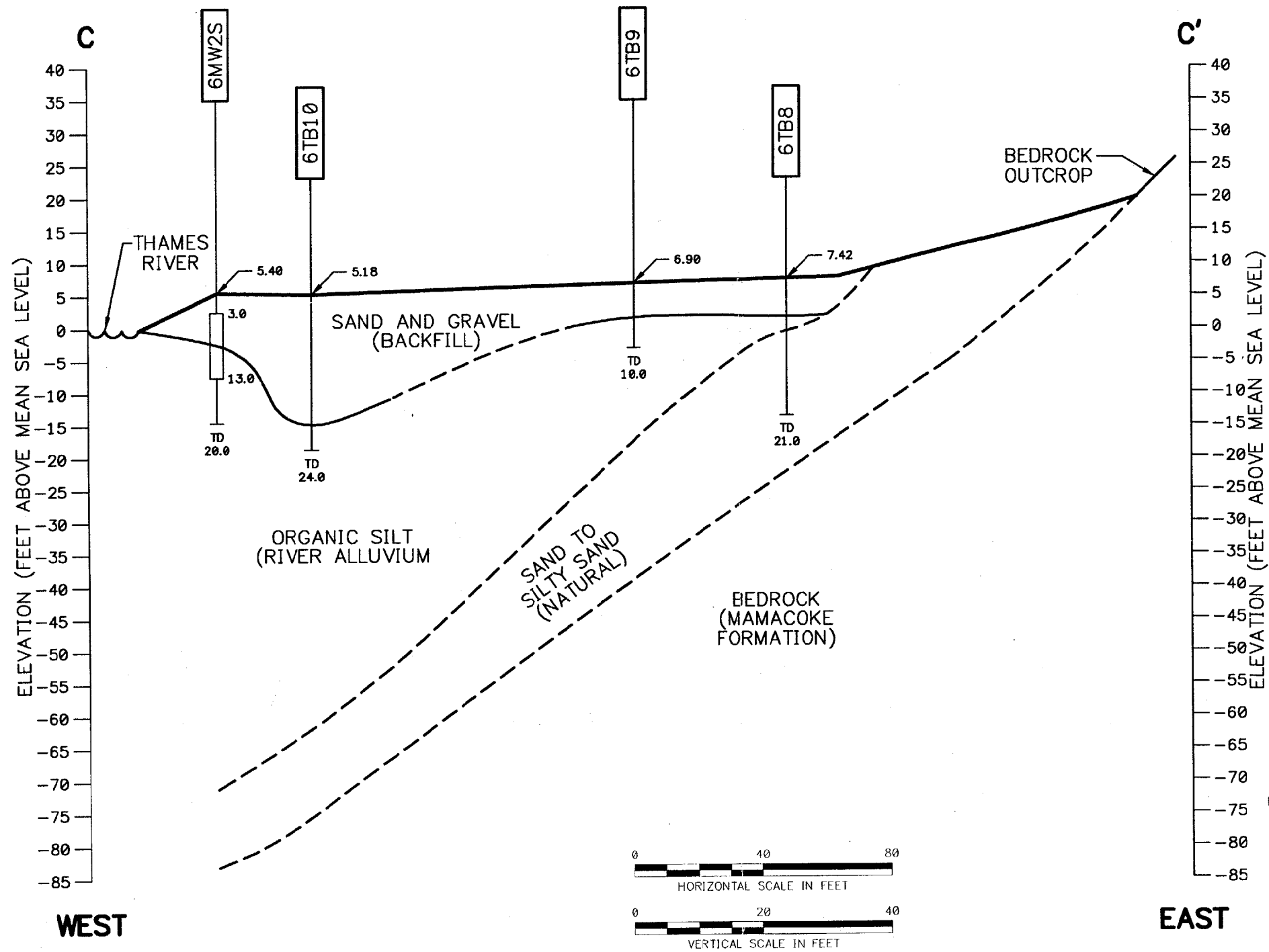
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NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE	CONTRACT NO.	OWNER NO.
							MF	2/14/98	7363	
							CHECKED BY	DATE	APPROVED BY	DATE
							COST/SCHED-AREA		APPROVED BY	DATE
							SCALE		DRAWING NO.	REV.
							AS NOTED		FIGURE 2-7	0

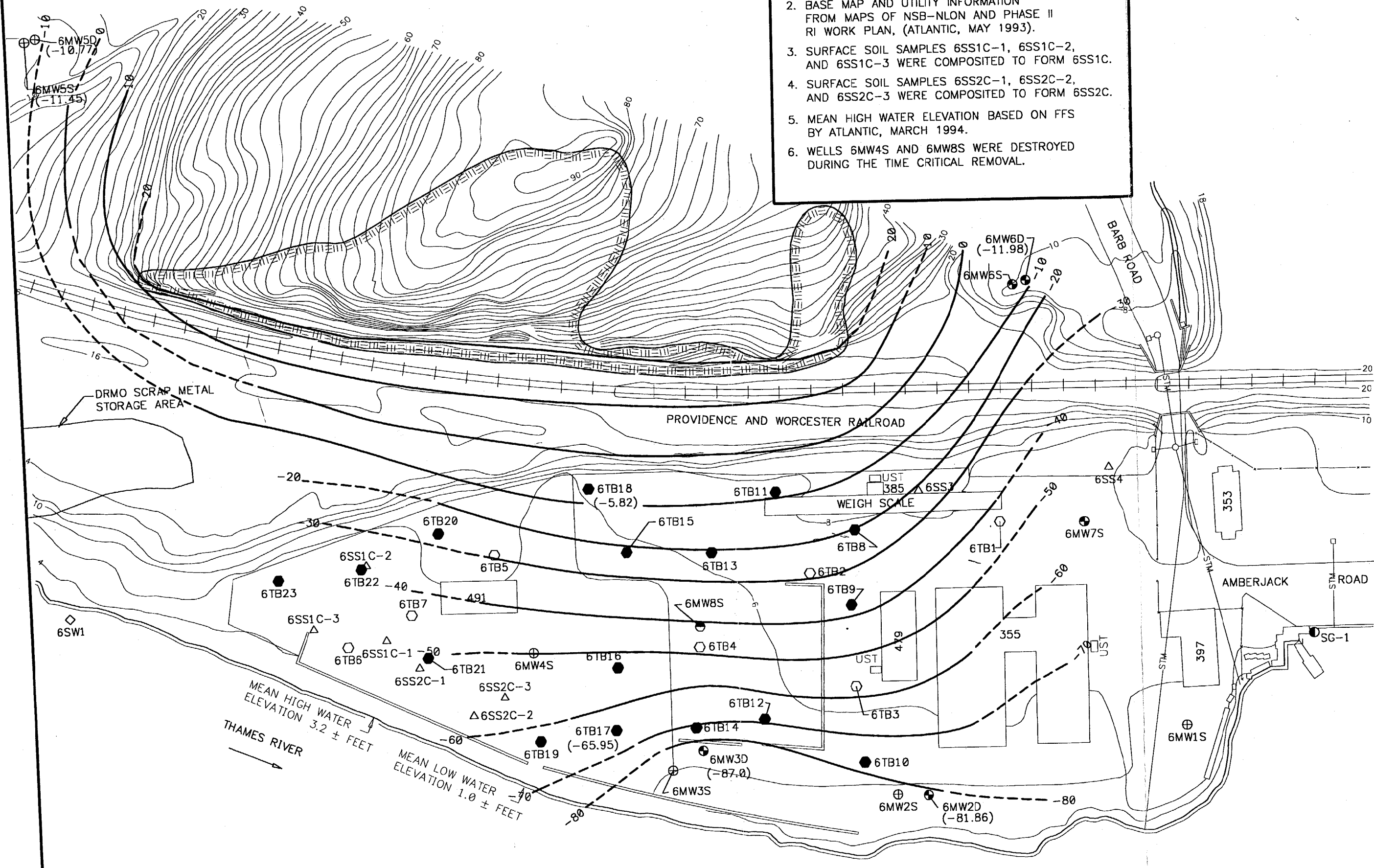
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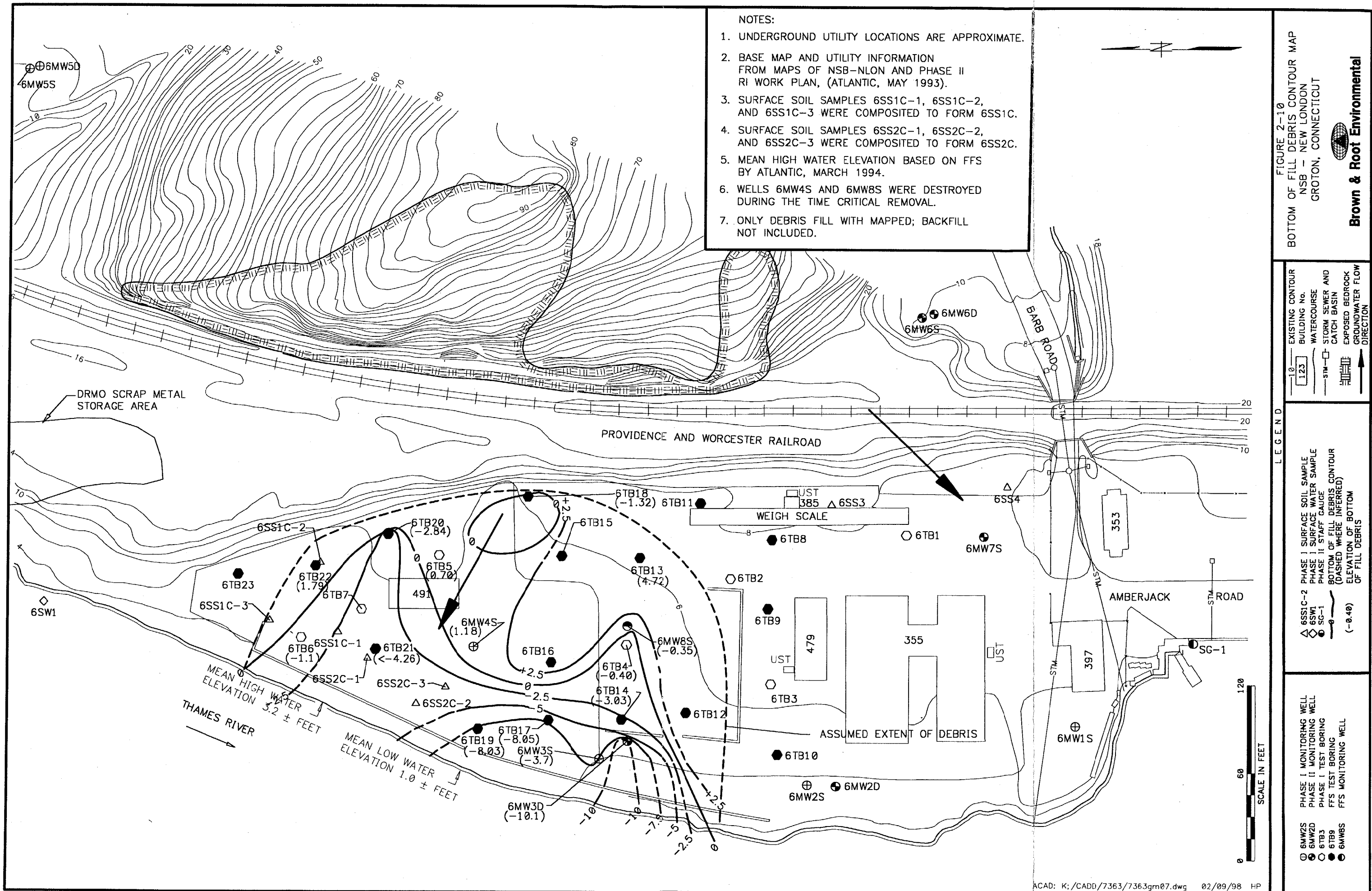


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							CHECKED BY	DATE	APPROVED BY	DATE
							COST/SCHED-AREA		APPROVED BY	DATE
							SCALE AS NOTED		DRAWING NO.	FIGURE 2-8
										REV. 0

FORM CADD NEL SOUTH\_BLDGN - REV 0 - 02/11/97







- NOTES:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
  2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON AND PHASE II RI WORK PLAN, (ATLANTIC, MAY 1993).
  3. SURFACE SOIL SAMPLES 6SS1C-1, 6SS1C-2, AND 6SS1C-3 WERE COMPOSITED TO FORM 6SS1C.
  4. SURFACE SOIL SAMPLES 6SS2C-1, 6SS2C-2, AND 6SS2C-3 WERE COMPOSITED TO FORM 6SS2C.
  5. MEAN HIGH WATER ELEVATION BASED ON FFS BY ATLANTIC, MARCH 1994.
  6. WELLS 6MW4S AND 6MW8S WERE DESTROYED DURING THE TIME CRITICAL REMOVAL.
  7. ONLY DEBRIS FILL WITH MAPPED; BACKFILL NOT INCLUDED.

FIGURE 2-10  
 BOTTOM OF FILL DEBRIS CONTOUR MAP  
 NSB - NEW LONDON  
 GROTON, CONNECTICUT

- LEGEND
- EXISTING CONTOUR
  - BUILDING NO.
  - WATERCOURSE
  - STORM SEWER AND CATCH BASIN
  - EXPOSED BEDROCK
  - GROUNDWATER FLOW DIRECTION

- 6SS1C-2 PHASE 1 SURFACE SOIL SAMPLE
- 6SW1 PHASE 1 SURFACE WATER SAMPLE
- SG-1 PHASE II STAFF GAUGE
- BOTTOM OF FILL DEBRIS CONTOUR (DASHED WHERE INFERRED)
- ELEVATION OF BOTTOM OF FILL DEBRIS (-0.40)

- 6MW2S PHASE I MONITORING WELL
- 6MW2D PHASE II MONITORING WELL
- 6TB3 PHASE I TEST BORING
- 6TB9 PHASE I TEST BORING
- 6MW6S FFS MONITORING WELL

TABLE 2-3

**POST-EXCAVATION SAMPLING RESULTS  
TIME-CRITICAL REMOVAL ACTION  
DRMO, NSB-NLON, GROTON, CONNECTICUT**

SAMPLE	DATE	TOTAL SOLIDS (%)	TOTAL LEAD (mg/kg)	TOTAL PCBs (mg/kg)	TOTAL cPAHs (mg/kg)
035	11/07/94	90.4	2900	47.2	1.62
036	11/07/94	92.8	1400	1.16	ND
037	11/07/94	87.0	650	0.97	58.08
038	11/07/94	91.9	365	1.34	ND
039	11/07/94	87.8	727	6.35	ND
040	11/07/94	85.5	3530	5.49	ND
041	11/07/94	84.4	2530	4.81	ND
042	11/21/94	91.7	3100	0.49	ND
043	11/21/94	84.6	824	2.16	102.69
044	11/21/94	86.1	21.2	ND	2.14
045	11/21/94	68.5	416	1.11	216.39
046	11/21/94	81.1	854	1.13	10.26
047	11/21/94	87.3	325	1.08	3.65
048	11/21/94	74.8	3180	0.90	42.26
049	11/21/94	67.9	2700	4.03	4.78
050	11/21/94	88.1	909	1.94	12.09
051	11/21/94	90.2	844	19.93	24.43
052	11/21/94	76.9	104	4.49	9.14
053	11/21/94	92.9	255	4.53	21.78
054	11/21/94	93.0	1220	2.26	20.79
055	11/21/94	92.0	802	3.83	22.03
056	11/21/94	91.6	388	2.29	3.15
057	11/21/94	82.2	1590	18.56	16.71
058	11/21/94	86.6	253	8.98	8.47
059	11/21/94	91.4	4540	2.03	6.71
060	12/07/94	93.2	15.6	ND	1.49
061	12/07/94	86.5	93.2	ND	5.90
062	12/07/94	89.2	2390	19.77	10.50
063	12/07/94	82.0	3350	29.2	40.18
064	12/07/94	87.3	1560	--	41.36
065	12/07/94	86.8	777	7.17	5.30
066	12/07/94	91.4	901	11.35	ND
067	12/07/94	90.3	1600	17.65	ND
068	12/07/94	92.9	1400	5.97	ND
069	12/07/94	91.4	482	8.18	ND
070	12/07/94	89.1	5520	9.25	ND
071	12/07/94	87.0	1230	10.8	15.75
072	12/07/94	87.8	1100	22.4	42.91
073	12/07/94	91.7	212	ND	2.40
074	12/07/94	87.5	374	ND	4.37
075	12/07/94	73.0	273	2.33	2.02

**TABLE 2-3 CONTINUED**  
**POST-EXCAVATION SAMPLING RESULTS**  
**DRMO, NSB-NLON, GROTON, CONNECTICUT**

SAMPLE	DATE	TOTAL SOLIDS (%)	TOTAL LEAD (mg/kg)	TOTAL PCBs (mg/kg)	TOTAL cPAHs (mg/kg)
076	12/07/94	94.0	7.8	ND	ND
077	12/07/94	86.8	5980	ND	22.14
078	12/07/94	71.2	4830	1.93	5.00
079	12/07/94	96.3	5	ND	0.96
080	12/07/94	97.2	5.52	ND	ND
081	12/07/94	94.4	5.94	ND	58.75
082	12/08/94	87.1	1030	2.29	ND

Reference: OHM, September 1995.

**NOTES:**

ND Compound was not detected above the method detection limit.  
 -- Sample was not analyzed for this parameter.  
 J Estimated value outside of method detection limits.  
 Total PAHs The sum of the following carcinogenic PAHs:  
     benzo(a)anthracenechrysene  
     benzo(b)fluoranthene                      dibenzo(a,h)anthracene  
     benzo(k)fluoranthene                      ideno(1,2,3-cd)pyrene  
     benzo(a)pyrene

### **2.3.2      Surface Water Features (Atlantic, August 1992)**

All surface water drainage flows west to the Thames River, which is located along the western edge of the DRMO. Two storm sewer systems exist along the southern side of the site which convey local discharge from the eastern side of the Providence and Worcester Railroad to the Thames River (B&R Environmental, March 1997).

### **2.3.3      Soil Characteristics**

The Soil Conservation Service (SCS) Soil Map (SCS, 1983) classifies the soil at the DRMO as Udorthents-Urban land complex. This soil type is defined as excessively drained to moderately drained soils that have been disturbed by cutting and filling. To the north of the site, the soil is classified as the Hinkley Loam. This soil is found on stream terraces and outwash plains and consists of a dark, gravely sand loam. Native materials at the DRMO were most likely of this type. Upslope of the site along the exposed bedrock high (northwest), the soil is classified as the Hollis-Charlton-Rock complex. This soil is defined as stones and boulders intermingled with a dark, fine, sandy loam. Bedrock outcrops are prevalent (B&R Environmental, March 1997).

### **2.3.4      Geology**

Geologic conditions at the DRMO consist of a westward-thickening wedge of overburden materials (fill and natural deposits) overlying fractured metamorphic bedrock. The DRMO is underlain by an upper layer of 2 to 20 feet of fill material. The fill consists primarily of sand and gravel but also contains metal and wood. The fill is thickest along the Thames River (6MW2D, 6TB10, 6TB12, 6TB16, 6TB17, and 6TB19) and thinnest at 6TB13 and 6TB15. There was no evidence of fill at 6MW7S (southeast corner of site) or the 6MW6 well cluster and the 6MW5 (offsite) well cluster (B&R Environmental, March 1997). Figure 2-4 shows the locations of the referenced wells and borings.

In most cases, the fill is underlain by clayey silt, which thickens from 2 feet along the eastern portion of the DRMO to a maximum observed thickness of 46 feet along the Thames River. The silt layer is underlain by sand and gravel, except at 6MW2D where the silt lies directly on bedrock. Upslope of the DRMO at the 6MW5 and 6MW6 well clusters, the clayey silt is missing and 20 feet of sand and gravel rest on bedrock. The coarse-grained natural overburden materials are generally mapped as terrace deposits along the Thames River (USGS, 1960). These terrace deposits are stratified drift of former glacial meltwater streams. At the DRMO, the coarse-grained terrace deposits are overlain by the clayey silt, which are finer-grained river bottom sediments (B&R Environmental, March 1997).

Bedrock in the northern portion of the DRMO has been mapped as the Granite Gneiss. Bedrock in the southern portion of the DRMO has been mapped as the Mamacoke Formation (USGS, 1967). These mapped formations were detected during drilling: the Granite Gneiss was encountered at 6MW5D and the Mamacoke Formation was encountered at 6MW6D. The Westerly Granite has been mapped along the eastern portion of the site, but it was not detected during drilling (Phase I RI). A bedrock high exists to the east of the DRMO and is an extension of the large bedrock high that borders the north part of NSB-NLON. The bedrock at the DRMO slopes westward toward the Thames River. The slope of the bedrock surface across the DRMO is approximately 25 percent (B&R Environmental, March 1997).

#### **2.3.5     Hydrogeology**

Groundwater is present within the overburden and bedrock underlying the DRMO. The water table is generally encountered within the fill materials at the site, with the underlying clayey silt and terrace deposits under saturated conditions. Based on the expected relative permeability of these three units (the coarse-grained fill and terrace deposits are expected to be significantly more permeable than the intervening clayey silt layer), the three deposits are considered to be separate hydrostratigraphic units. The clayey silt may function as an aquitard relative to the overlying and underlying coarser grained units (B&R Environmental, March 1997).

Groundwater flow is generally from east to west, following topographic and bedrock surface slope to the Thames River. Due to the proximity of the site to the river and the demonstrated influence of tides on groundwater levels near the river at the Lower Subase, it is expected that tidal fluctuations of the river locally affect groundwater levels, at least in the western portion of the DRMO. Tidal influences on groundwater are discussed in Section 2.3.6.

Figure 2-4 shows shallow overburden groundwater flow contours for the DRMO (based on August 1994 data). During August 1994, water level measurements were collected around low tide and varied from 2.45 to 10.84 feet below ground surface across the site unit. As is expected groundwater flow is westward towards the Thames River. Groundwater flow directions in the bedrock are expected to be similar to the overburden flow directions. The bedrock high to the east and upgradient of the DRMO maintains a groundwater elevation of approximately 3 feet. There are some irregularities in the groundwater elevations across the DRMO, which are most likely attributable to local bedrock irregularities and to the heterogeneity of the overburden (B&R Environmental, March 1997).

No clear patterns for vertical groundwater flow are evident from the water level data. At well cluster 6MW2S/2D (Figure 2-4), an upward flow gradient was observed between the fill and terrace deposits during two of the three comprehensive water level measuring rounds. At cluster 6MW3S/3D, a downward gradient was observed between the fill and terrace deposits during two of the three measurement rounds. At cluster 6MW5S/5D, a upward gradient was observed between the bedrock and terrace deposits during two of three measurement rounds, while at cluster 6MW6S/6D, a downward gradient between the fill and bedrock was observed during all three water level rounds. Vertical gradients are expected to fluctuate significantly near the river, due to tidal fluctuations and the resulting impacts on groundwater levels. Shallow overburden groundwater levels are expected to vary in response to the tides, more than deeper groundwater, due to a more direct hydraulic connection between the shallow overburden and river in comparison to deeper groundwater flow zones (B&R Environmental, March 1997).

Slug tests were performed at the 6MW7S and 6MW3D wells during the Phase II RI (Figure 2-4). The estimated hydraulic conductivity at 6MW7S was 1.9 feet/day ( $6.7\text{E-}4$  cm/sec). The well was screened primarily in dense gravel fill. The estimated hydraulic conductivity at 6MW3D was 20.3 feet/day ( $7.2\text{E-}3$  cm/sec). Although 6MW3D is deeper than 6MW7S, it is located on the margin of the DRMO along the Thames River and is screened in loose sand and gravel alluvium (terrace deposits) (B&R Environmental, March 1997).

The average hydraulic conductivity of the fill materials was calculated by taking the geometric mean of DRMO-specific hydraulic conductivities (both Phase I RI and Phase II RI) for two wells completed within the fill materials. Hydraulic conductivities from Phase I RI well 6MW2S (70 ft/day) and from Phase II RI well 6MW7S (1.9 ft/day), were used to calculate the geometric mean. Hydraulic conductivities were estimated at these wells based on a slug test (6MW7S) and a single well pumping test (6MW2S) results. The average hydraulic gradient was calculated using groundwater measurements from March and August 1994 (B&R Environmental, March 1997).

The volumetric rate of shallow groundwater discharge from the fill materials at the DRMO to the Thames River was estimated using site-specific information. Since the underlying clayey silt layer likely acts to minimize groundwater impacts from the DRMO to the deep river bottom and alluvial deposits, the groundwater flux from the DRMO to the river was calculated from the fill only. The groundwater discharge rate from the DRMO to the Thames River was calculated as 1,666 cubic feet/day using Darcy's equation:

$$Q = K * I * A$$

Where:

- Q: Groundwater Discharge Rate (cubic feet/day)
- K: Hydraulic Conductivity (11.5 feet/day)
- I: Hydraulic Gradient (0.0115)
- A: Hydraulic Cross-section (15 feet saturated thickness x 840 feet DRMO Thames River frontage)

The actual discharge rate is likely to be substantially lower than this calculated rate, as tidal effects were not considered. During periods of high tide, groundwater discharge to the river is expected to be halted as gradients reverse and the river recharges the groundwater (B&R Environmental, March 1997).

Generic contaminant loading rates for groundwater discharge into the Thames River from the DRMO site were generated using the following:

- An estimated groundwater discharge rate (Q, discounting tidal effects) of 1,666 cubic feet/day,
- A 0.75 factor applied to this flux rate to account for the lack of groundwater discharge during periods of high tide (assumed about 6 hours/day over 2 tidal cycles),
- Hypothetical solute concentrations (C) of 10, 100, and 1,000  $\mu\text{g/L}$ , and
- The following mass flux equation ( $\text{mass flux} = Q \times 0.75 \times C$ ).

The corresponding daily discharge rates from the DRMO into the Thames River are  $7.80\text{E-}4$ ,  $7.80\text{E-}3$ , and  $7.80\text{E-}2$  lbs/day for solute concentrations of 10, 100, and 1,000  $\mu\text{g/L}$ , respectively. Actual discharge rates for individual dissolved constituents can be approximated by using these generic discharge rates and the average concentration of the constituent. For example, a compound present at an average concentration of 25  $\mu\text{g/L}$  in groundwater would have a loading rate 2.5x the generic rate calculated for a solute present at the 10  $\mu\text{g/L}$  concentration. This loading estimate does not factor in retardation and degradation of solutes, which may be substantial in some cases and would reduce the loading rate (B&R Environmental, March 1997).

### **2.3.6 Groundwater Tidal Influences**

The DRMO site is approximately 4-acres in size and is located adjacent to the Thames River. A large portion of the site along the river was originally below high tide elevation and has since been covered with fill. The fill material was placed directly on top of river sediments in most areas (Atlantic, March 1995). The land surfaces are now above the high tide elevation although much of the site is located within the 100 year flood plain (OHM Corporation, September 1995).

Groundwater elevations in the overburden aquifer are approximately 3 to 6 feet below grade in the southern portion of DRMO and approximately 12 feet below grade in the northern portion of DRMO (Atlantic, March 1995).

Groundwater flow is generally from east to west (see Figure 2-4), following the topographic and bedrock surface slope to the Thames River. The Thames River is tidally influenced with a mean tidal range at the NSB-NLON of 2.2 feet, which creates reversals in groundwater flow directions and causes water levels to fluctuate by 1.19 feet in monitoring wells. Due to the proximity of the site to the river, and the demonstrated influence of tides on groundwater levels near the river at the Lower Subbase, it is expected that tidal fluctuations of the river locally affect groundwater levels, at least in the western portion of the DRMO.

During low tide, the hydraulic gradient of the groundwater table at NSB-NLON is towards the Thames River and will result in the highest discharge rate of groundwater to the river. During high tide, the hydraulic gradient of the groundwater is reversed and flow occurs from the river to the site, temporarily halting the discharge of groundwater from the base to the river. The reversal of groundwater flow direction at high tide generally occurs within 300 feet of the river (B&R Environmental, March 1997).



### **3.0 GROUNDWATER MONITORING SYSTEM INSTALLATION**

This section describes the drilling and installation procedures for three new monitoring wells and subsequent installation of low flow sampling pumps to be used at the DRMO for groundwater monitoring activities. Pump operation and monitoring procedures are also discussed below. Field activities will be performed in accordance with Navy CLEAN, OSHA 1910.120, and B&R Environmental health and safety procedures. An addendum to the Health and Safety Plan written for the Phase II RI work will be prepared.

#### **3.1 MONITORING WELL INSTALLATION**

The Phase I and II RIs identified two permeable zones, the surficial fill and the deeper terrace deposit unit, separated by a low-permeability unit of clayey silt underlying the DRMO. The surficial fill unit ranges in thickness from 2 to 20 feet and acts as an unconfined aquifer, hydraulically connected to the Thames River. The terrace deposit unit is the first permeable zone encountered below the clayey silt unit. Therefore, the objective of the installation and sampling of new monitoring wells will be to obtain data about these two permeable zones.

Two new monitoring wells (6MW9S and 6MW10D) will be drilled and installed to the bedrock surface and one new shallow monitoring well (6MW10S) at the locations shown on Figure 3-1. The location of well 6MW9S will be immediately upgradient from the existing well (6MW3S) and will be located outside the perimeter of the cap. Well 6MW9S will be installed to the bedrock surface which is estimated to be 12 to 15 feet below ground surface, based on previous investigations. This location will be used to assess whether offsite sources are contributing contamination to the DRMO. The location of well 6MW10S will be along the western edge of the site adjacent to the Thames River. Based upon existing stratigraphic and hydrogeologic data and upon existing monitoring well in formation, this well will be installed and screened to a depth of 12 to 15 feet to allow sampling of the shallow groundwater. This well will be used to assess the groundwater leaving the DRMO site. Well 6MW10D will also be installed along the western edge of the site adjacent to well 6MW10S. Based upon existing stratigraphic and hydrogeologic data and upon existing monitoring well in formation, this well will be installed and screened to the bedrock surface which is estimated to be 80 to 85 feet below ground surface in this area to allow sampling of the deep groundwater. The proposed screen length for well 6MW10D is 10 feet. This well will also be used to assess the groundwater leaving the DRMO site.

The wells will be constructed of 2-inch I.D. National Sanitary Foundation (NSF) approved flush-joint polyvinyl chloride (PVC) riser pipes and flush-joint factory slotted PVC well screens no larger than

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NOTES:

1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON AND PHASE II RI WORK PLAN, (ATLANTIC, MAY 1993).
3. POTENTIOMETRIC SURFACE FOR WATER LEVELS MEASURED ON AUGUST 23-24, 1994.
4. MEAN HIGH WATER ELEVATION BASED ON FFS BY ATLANTIC, MARCH 1994.

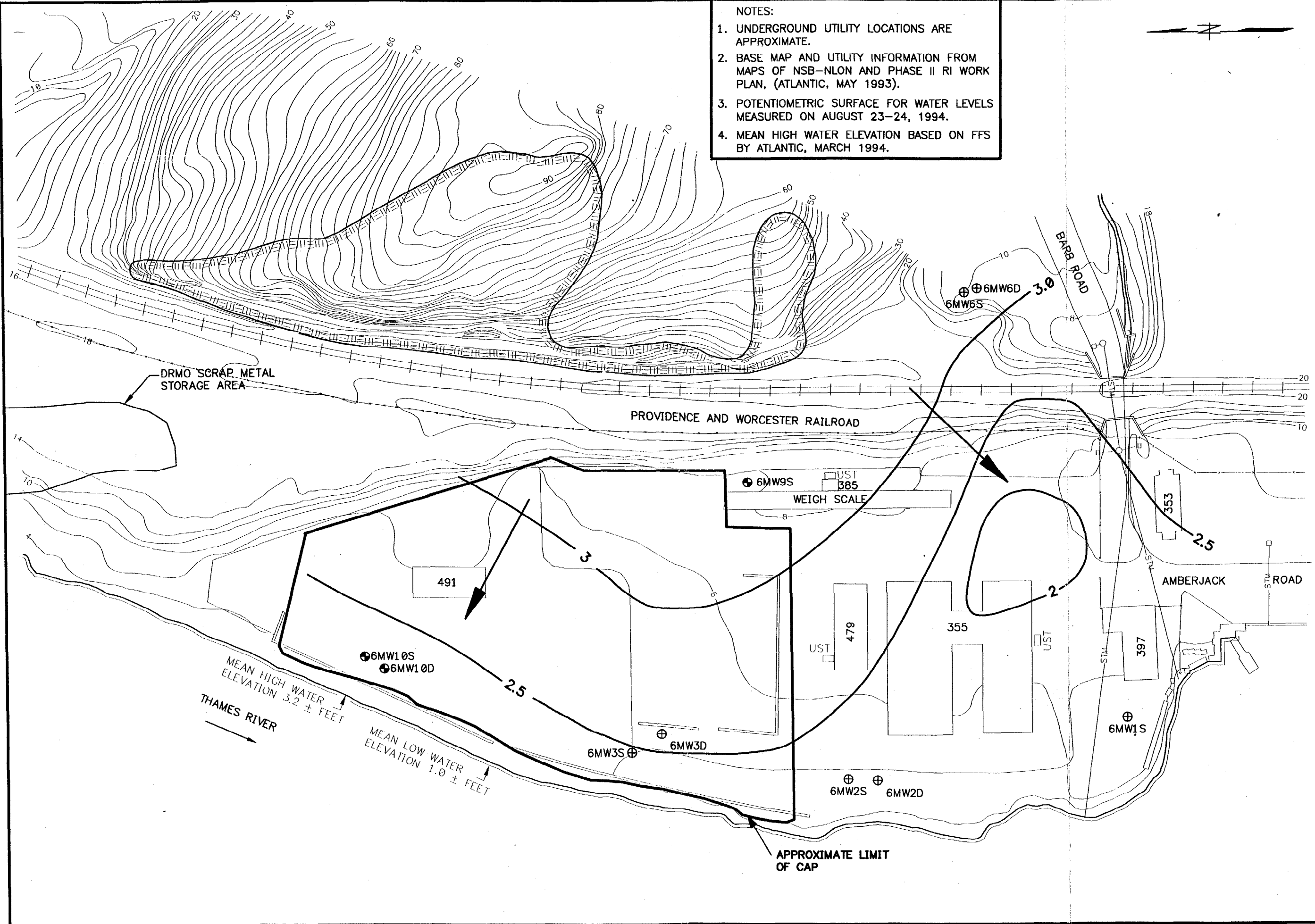
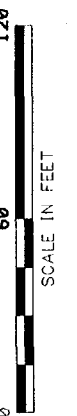


FIGURE 3-1  
PROPOSED MONITORING WELL LOCATIONS  
NSB - NEW LONDON  
GROTON, CT

Brown & Root Environmental

LEGEND	
⊕ 6MW5S	EXISTING MONITORING WELL
⊕ 6MW9S	PROPOSED WELL LOCATION
— 80 —	POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
→	GROUNDWATER FLOW DIRECTION
— 10 —	EXISTING CONTOUR
— 10 —	WATERCOURSE
— STM —	STORM SEWER AND CATCH BASIN
— 10 —	EXPOSED BEDROCK
— 10 —	FENCE



0.01 inches. The top of the screened interval will be positioned approximately 3 feet below ground surface (bgs) to the bottom of each well. After each boring (8-inch minimum diameter boring) is drilled to the desired depth, the well screen and riser pipe will be installed through the augers to the desired depth. The annulus of the boring around each well screen will be backfilled with clean silica sand (No. 20 to 30 U.S. Standard Sieve size or as determined by the site geologist). A minimum 2-foot thick bentonite pellet seal will then be installed above the sand pack and allowed to hydrate as per the manufacturers recommendations. The remainder of the boring annulus will then be backfilled with a cement/bentonite grout placed using a tremie pipe. The depth of all backfilled materials will be monitored using a weighted stainless steel or plastic tape. Figure 3-2 shows a typical flush mount monitoring well cross section.

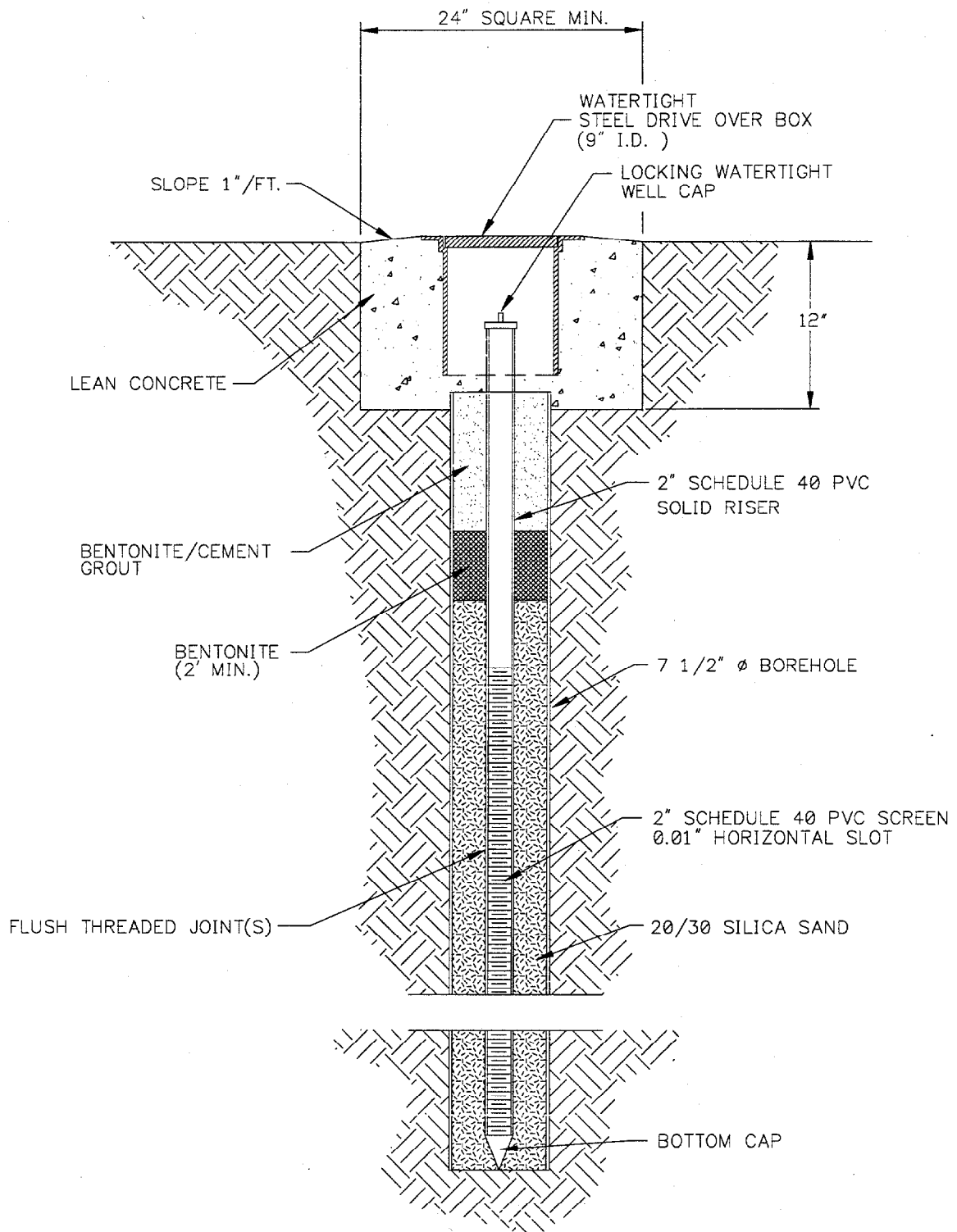
The monitoring wells will be completed with a 2-foot by 2-foot concrete surface seal and a 12-inch diameter protective steel flush mounted vault box such that the concrete collar extends from the vault box in all directions. The vault box will be secured by bolts. The top of the vault box will have sufficient clearance extending down to the top of the PVC riser to allow for the installation of the necessary well cap assembly to be installed with the low-flow bladder pump.

As shown on Figure 3-1, wells 6MW10S and 6MW10D will be installed within the limits of the composite cap. The locations were selected due to access limitations to downgradient areas along the Thames River. Once installation is completed, the cap materials will be removed to the depth of the geocomposite liner. The vault box and concrete seal will then be installed to ensure an adequate seal is formed around the new wells and to minimize any affects on the integrity of the capping system.

### **3.2 LOW-FLOW PUMP INSTALLATION AND OPERATION**

At the completion of drilling activities, dedicated low flow sampling pumps will be installed in the three newly drilled monitoring wells and seven existing wells. It is expected that teflon-lined PVC bladder type pumps with intake screens capable of fitting a 2-inch well will be installed into each of the monitoring wells. The pumps will be capable of low-flow purging (minimum 100 ml per minute) and sampling. The pump intake will be placed no lower than 2-feet from the bottom of the well.

Well cap assemblies for 2-inch monitoring wells completed with quick connect fittings for twin-bonded teflon lined polyethylene air supply and sample tubing will be custom fitted to each of the pumps and monitoring wells. The existing monitoring wells will be evaluated prior to assembly of the well cap to ensure that there is sufficient clearance from ground surface to the top of the riser pipe. A pneumatic pump controller and oil-free bottled compressed air will be used to operate the pumps. The type of compressed gas used for operation of the pumps will be in accordance with the manufacturers



**TYPICAL FLUSHMOUNT  
MONITORING WELL  
NSB — NEW LONDON  
GROTON, CT.**

**FIGURE 3-2**



**Brown & Root Environmental**

recommendations. Actual purging and sampling will be performed in accordance with the U.S. EPA Region I's Low-Flow Purging and Sampling procedure (U.S. EPA, July 30, 1996) discussed in Section 4.0

## **4.0 SAMPLING AND ANALYSIS**

The following section describes the sampling and analysis procedures to be followed during performance of groundwater monitoring at the DRMO. In addition, the necessary Quality Assurance (QA) and Quality Control (QC) requirements are presented herein.

In accordance with standard Navy CLEAN procedures, OSHA 1910.120 and B&R Environmental health and safety procedures, all field team members will be cleared by the CLEAN Health and Safety Manager prior to working on this (or any) project. A project-specific Health and Safety Plan Addendum will be prepared prior to conducting field activities.

### **4.1 SAMPLING AND ANALYSIS PROCEDURES**

#### **4.1.1 Groundwater Monitoring**

Groundwater sampling will be conducted at seven existing monitoring well location and three new monitoring well locations. In order to collect representative samples of site groundwater, sampling will be consistently performed during periods of low tide. During the first year of sampling, the groundwater samples and duplicates will be analyzed for full Target Compound List/Target Analyte List (TCL/TAL) constituents. Samples and duplicates will not be analyzed for cyanide. Table 4-1 provides analytical methods, containers, preservation and holding times for each parameter. In addition, a trip blank will be collected during each sample event and analyzed for full TCL volatile constituents only. No field blanks or equipment rinsate blanks will be collected because dedicated pumps are being used for sample collection. Table 4-2 presents the number of samples, including QA/QC samples, for the first sampling event.

Following the first year of sampling events (4 rounds of sampling), the analytical data will be reviewed and a revised analytical suite will be proposed if appropriate. Samples will be analyzed for TCL/TAL constituents, as appropriate. Any changes to the monitoring program will be recommended in the monitoring reports for review and approval by the regulatory agencies. Sampling/analysis will be performed on a quarterly (4 times a year) basis for the first year and is anticipated to take place twice a year for two additional years. Sampling schedule may be arranged to avoid the coldest months when it is possible for the wells to freeze (e.g., December, March, June, and September). The actual months selected for sampling may vary from year to year to gain information associated with seasonal changes. Sampling/analysis frequency and revisions to that frequency will be determined with concurrence from the regulatory agencies.

TABLE 4-1

**SUMMARY OF SAMPLE ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS, AND HOLDING TIMES  
GROUNDWATER MONITORING PLAN  
DRMO, NSB-NLON, GROTON, CONNECTICUT**

Parameter	Sample Container	Container Volume	Preservation <sup>(1)</sup>	Maximum Holding Time	Analytical Methodology
<b>GROUNDWATER</b>					
TCL Volatile Organic Compounds	Glass, black phenolic plastic screw cap, Teflon-lined	40 mL	Cool to 4°C, dark, HCl to pH < 2	14 days	U.S. EPA-CLP SOW for Organic Analysis, Low Concentration (Doc. #OLC02.0) <sup>(2)</sup>
TCL Semivolatile Organic Compounds	Amber glass, Teflon-lined cap	2,000 mL	Cool to 4°C, dark	Extraction 7 days; analysis within 40 days	U.S. EPA SW-846 Method 8310 and 8270B <sup>(3)</sup>
TCL Polychlorinated Biphenyls and Pesticides	Amber glass, Teflon-lined cap	2,000 mL	Cool to 4°C, dark	Extraction 7 days; analysis within 40 days	U.S. EPA-CLP SOW for Organic Analysis, Low Concentration (Doc. #OLC02.0)
TAL Metals (total and dissolved)	Polyethylene bottle, plastic cap, plastic liner	1,000 mL	Cool to 4°C, HNO <sub>3</sub> to pH < 2	Within 180 days; mercury within 28 days	U.S. EPA-CLP SOW for Inorganic Analysis, Multi-Media, Multi-Concentration (Doc. #ILM04.0) <sup>(4)</sup>

**NOTES:**

- (1) Preservation agents: HCl = Hydrochloric acid, HNO<sub>3</sub> = Nitric Acid  
 (2) U.S. EPA (United States Environmental Protection Agency) CLP, 1994. Statement of Work for Organic Analysis, Low Concentration, OLC02.0.  
 (3) U.S. EPA (United States Environmental Protection Agency) SW-846, 1994. Test Methods for Evaluating Solid Waste, Method 8310 and 8270B.  
 (4) U.S. EPA (United States Environmental Protection Agency) CLP, 1995, Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration; ILM04.0.



TABLE 4-2

**ANALYTICAL PROGRAM SUMMARY  
FIRST SAMPLING EVENT  
GROUNDWATER MONITORING PLAN  
DRMO, NSB-NLON, GROTON, CONNECTICUT**

Media	Analysis	Analytical Method	Environmental Samples	Trip Blanks <sup>(1)</sup>	Duplicates <sup>(2)</sup>	Total Samples
Groundwater	TCL volatile organics	CLP OLM03.1	10	1	1	12
	TCL semi-volatile organics	CLP OLM03.1	10	-	1	11
	TCL pesticide/PCBs	CLP OLM03.1	10	-	1	11
	TAL inorganics <sup>(3)</sup> (Total)	CLP ILM04.0	10	-	1	11
	TAL inorganics <sup>(4)</sup> (Filtered)	CLP ILM04.0	10	-	1	11

**NOTES:**

Additionally, specific conductance, pH, salinity, turbidity, temperature, and Oxidation Reduction Potential (Eh) will be measured in the field.

- (1) Trip Blanks - Samples which originate from analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic samples. One trip blank per each cooler containing volatile organics.
- (2) Duplicates - A single sample split into two portions during a single act of sampling. Assess the overall precision of the sampling and analysis program.
- (3) Total Metals - For the determination of total metals the sample is not filtered before acidification.
- (4) Dissolved Metals - For the determination of dissolved metals the sample is field filtered to 0.45 $\mu$  before acidification according to Brown & Root Environmental SOP SA-6.1 attached in Appendix B.

#### **4.1.2      Inspection of Existing Monitoring Wells**

Prior to sampling each monitoring well, a brief inspection will be conducted, evaluating the following conditions:

- Condition of the protective casing
- Condition of the cement seal surrounding the protective casing
- Presence of any standing water around the protective casing
- Presence of dedicated sampling equipment
- Determination of static water level
- Determination of total depth of well, including a check to determine if well is obstructed
- Well security evaluation

Comparisons will be made between baseline conditions and sampling date conditions to determine if significant changes have occurred which may indicate well damage. A record of all field observations will be recorded in a field log book.

#### **4.1.3      Water-Level Measurement**

Two rounds of water-level measurements will be conducted for each sampling event to provide information regarding groundwater flow patterns and flow gradients across the DRMO facility. Water-levels will be obtained from the ten monitoring wells; one round during mean high tide and one round during mean low tide. Each round of water-level measurements will be completed within the shortest time possible on the same day, and no sooner than 24 hours after a significant precipitation event, to minimize the precipitation effects, on the data sets.

Water-level measurements will be taken with an M-Scope (electric water-level indicator) using the top of the inner well casing as the reference point for determining depths to water. This well casing shall be notched and marked so that the same point will be referenced for all measurements. M-scopes will be calibrated prior to each sampling event by comparison of M-scope markings with a steel tape measure. Water-level measurements will be recorded to the nearest 0.01 foot in the field logbook and on a groundwater level measurement form, attached in Appendix A. The date and time that each measurement was taken will also be recorded. B&R Environmental Standard Operating Procedure (SOP) GH-1.2, which is included in Appendix B, provides a description of Water Level Measurement procedures.

Surface water measurements will be obtained by installing a staff gage in the surface water body and collecting measurements from a known reference point to the surface water elevation. A standard USGS

staff gage or permanent feature will be used as a reference point for measurements. The staff gage will be permanently marked by the field operations leader indicating referenced points of measurement. The referenced points will be subsequently surveyed for location and elevation. Surface water elevations will be recorded to the nearest 0.01 foot.

#### **4.1.4     Well Purging**

It is anticipated that dedicated 2-inch diameter low-flow bladder type pumps will be installed in the three monitoring wells prior to the baseline sampling. The pumps will be certified contaminant free; this certification, as well as lot numbers, will be provided in an appendix of the initial groundwater monitoring report. Purging and sampling will be accomplished by using low-flow purging techniques in accordance with B&R Environmental's SOP SA-1.1 (Groundwater Sample Acquisition) and U.S. EPA Region I's Low-Flow Purging and Sampling Procedure (U.S. EPA, July 30, 1996), both of which are included in Appendix B. Low-flow purging and sampling is being implemented because this method will provide the least disturbance to the surrounding formation (i.e., less turbulence in sampling and hence less turbidity) allowing for a more representative sample to be collected.

Prior to obtaining groundwater samples, water levels will be measured using an M-Scope. Water levels will be monitored every 3 to 5 minutes as purging occurs. Each monitoring well will be purged and sampled using a dedicated, low-flow 2-inch diameter bladder pump and dedicated teflon or teflon-lined polyethylene tubing. The pump will be placed at the midpoint of the well screen and if possible no less than 2 feet above the bottom of the well so as to not disturb any sediment which may be located near the bottom of the well. Initially, the pumping rate will be set at approximately 0.3 liters per minute, not to exceed 0.5 liters per minute. The pumping rate will be reduced to 0.1 to 0.2 liters per minute if turbidity is greater than 5 nephelometric turbidity units (NTUs) after all other field parameters have stabilized. The pumping rates will be adjusted so as to not allow draw down to exceed 0.3 feet during the purging. If groundwater is drawn down below the top of the well screen purging will cease and the well will be allowed to recover before purging continues. Slow recovering wells will be identified and purged at the beginning of the work day. If possible samples will be collected from these wells within the same 8-hour work day.

During purging, water quality parameters (pH, turbidity, specific conductance, temperature, Eh, salinity, and dissolved oxygen) will be measured and recorded every 5-minutes using a flow-through cell until all of the parameters have stabilized and the minimum purge volume has been removed (2-saturated well screen volumes). Stabilization of the above parameters is defined as follows:

- pH + 0.2 standard units
- turbidity + 10 %
- specific conductance + 10 %
- temperature + 10 %
- Eh + 10 %
- dissolved oxygen + 10 %

Calibration and standards checks will be conducted on the flow-through cell in accordance with the manufacturer and U.S. EPA Region I's low-flow guidance.

Purge water will be containerized in Department of Transportation (DOT)-approved (Specification 17-C), 55-gallon drums. Refer to Section 4.1.7 concerning waste handling.

B&R Environmental SOP SA-1.1, attached in Appendix B, provides additional requirements for groundwater sample acquisition.

#### **4.1.5      Sampling of Wells**

Wells sampled as part of the monitoring event will be sampled using a low-flow 2-inch diameter low flow bladder-type pump and dedicated teflon or teflon-lined polyethylene tubing. Samples will be collected directly from the discharge of the pump.

All sample containers should be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. Samples to be analyzed for VOCs will be taken first and immediately sealed in a pre-preserved container so that no head space exists. For filtered inorganic samples, an in-line 0.45 micron filter will be used. The filter will be pre-rinsed with approximately 400 ml of deionized water and attached to the discharge end of the pump tubing.

The monitoring wells are tidally influenced, therefore groundwater samples will be collected at low tide. At low tide, contaminant concentrations are expected to be at maximum concentration, therefore, providing conservative data (at high tide, inflow of "clean" water would potentially dilute the contaminants in tidally influenced wells).

After sampling, the discharge piping will be drained to prevent possible freezing. Care will be taken not to contaminate the exterior of the tubing (via contact with the ground or clothing) while conducting this activity.

#### **4.1.6      Decontamination**

Nondedicated equipment involved in field sampling activities will be decontaminated prior to and during sampling activities. Since dedicated sampling equipment will be used at each well location to the extent possible, little to no decontamination water will be generated. Any decontamination water that is generated will be handled in the same manner as purge water, described in Section 4.1.7.

Drilling equipment will be decontaminated using steam cleaning equipment and potable water supplied by NSB-NLON.

For any non-dedicated sampling equipment used for collecting groundwater samples, the equipment will be decontaminated both prior to beginning field sampling and between samples. The following decontamination steps will be conducted.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Potable water rinse
- 10% Nitric acid rinse diluted with deionized water
- Methanol Rinse
- Analyte-free water rinse
- Air dry
- Wrap in aluminum foil

Field analytical equipment such as pH, conductivity and temperature instrument probes will be rinsed first with analyte-free water, then with the sample liquid. All decontamination activities will be performed over a container, and fluids will be containerized for proper disposal.

#### **4.1.7      Waste handling**

Two types of potentially contaminated residues are expected to be generated during the groundwater monitoring program, namely Personal Protective Equipment (PPE) and purge water. Based on the activities and types of contaminants present, none of these residues are expected to represent a significant risk to human health or the environment if properly managed. Planned management of each of these residues is provided below:

PPE - B&R Environmental will place uncontaminated PPE in the trash receptacles at the facility. If visually contaminated, PPE will be containerized in the same manner as the decontamination and purge liquids.

Purge Water - All decontamination and purge liquids will be collected, containerized, and stored on site in Department of Transportation (DOT)-approved (Specification 17-C), 55-gallon drums. All drums will be sealed and labeled with drum contents, monitoring well number, site, volume, and date. The drums will be stored at a centralized location on base pending analyses results. B&R Environmental will dispose of the waste in an appropriate manner based on the analytical results.

#### **4.1.8      Sample Identification System**

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a two-segment, alpha-numeric code that identifies the sample medium and location, and sample round identifier (in the case of groundwater samples). Any other pertinent information regarding sample identification will be recorded in the field log books.

The alpha-numeric coding to be used in the sample system is explained in the diagram and the subsequent definitions:

<b>(AAAA)</b>	-	<b>(NAANNA)</b>	-	<b>(AA)</b>	-	<b>(NN)</b>
(Site ID)		(Location)		(Medium)		(Round Identifier)

Character Type:

A	=	Alpha
N	=	Numeric

Site ID:

DRMO = Defense Reutilization and Marketing Office

Sample Location:

6MW03S = Monitoring well number

Media:

GW = Groundwater

**Sample Round Identifier:**

For all samples = sampling round

- First event, Round 1
- Second event, Round 2
- Subsequent Sampling, Round 3, 4, etc.

For example, a groundwater sample collected from monitoring well 6MW03S at DRMO during the second round would be designated as: DRMO-6MW03S-GW-02.

Field quality control (QC) samples are described in Section 4.4.3. They will be designated using a different coding system. The QC code will consist of a two-segment, alpha-numeric code that identifies the sample medium (for duplicates only), QC type, and date. The same sample medium codes will be used as for the standard environmental samples (i.e., GW). The QC types are identified as:

TB = Trip Blanks

FD = Field Duplicates

For example, a duplicate of a groundwater sample obtained on June 3, 1996 would be designated as: GWFD-060396. This allows duplicates to be submitted as "blind" samples to the analytical laboratory. Sample log sheets, not received by the analytical laboratory, will document duplicate sample location.

The sampling time recorded on the chain-of-custody form for duplicate samples will be 00:00 so that the samples are "blind" to the laboratory. Notes detailing the sample number, time, date, and type will be recorded in the field log book and on sample log sheets. A separate sample log sheet will be completed for duplicate samples sent blind to the laboratory.

#### **4.1.9 Sample Handling**

Sample handling includes the field related considerations connected with the selection of sample containers, preservatives, allowable holding times, and analyses requested. Table 4-1 provides a summary of all sample handling considerations. B&R Environmental SOP SA-6.1, attached in Appendix B, provides a description of the sample preservation requirements.

#### **4.1.10 Chain-of-Custody**

Sample custody procedures are designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. An example of the chain-of-custody form, which will be used during this

investigation, is included in Appendix A. A copy of the procedure is included in B&R Environmental SOP SA-6.3, which is included in Appendix B.

Integrity of the samples collected during the site investigation will be the responsibility of identified persons from the time they are collected until they, or their derived data, are incorporated into the final report. Stringent chain-of-custody procedures will be followed to document sample possession.

### **Field Custody**

- The B&R Environmental Field Operations Leader (FOL) is responsible for the care and custody of the samples collected until they are delivered to the analyzing laboratory or entrusted to a carrier.
- Sample logs or other records will be signed and dated.
- Chain-of-custody sample forms will be completed to the fullest extent possible prior to sample shipment. They will include the following information: project name, sample number, time collected, source of sample and location, description of sample location, matrix, type of sample, grab or composite designation, preservative, and name of sampler (see attached form).

These forms will be filled out in a legible manner, using waterproof ink, and will be signed by the sampler. Similar information will be provided on the sample label which will be securely attached to the sample bottle. The label will also include the general analyses to be conducted. In addition, sampling forms will be used to document collection, filtration, and preparation procedures. Copies of all forms used during field activities are provided in Appendix A.

### **Transfer of Custody and Shipment**

The following procedures will be used when transferring custody of samples:

- Samples will be accompanied by a chain-of-custody record. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time of the chain-of-custody record. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common carrier). Upon arrival at the laboratory, internal sample custody procedures will be followed.



- Prior to shipment to the laboratory for analysis, samples will be properly packaged. Individual custody records will accompany each shipment. Shipping containers will then be sealed for shipment to the laboratory. The methods of shipment, courier name, and other pertinent information, will be entered in the remarks section of the custody record.
- All shipments will be accompanied by the chain-of-custody record identifying the contents. The original record will accompany the shipment; and a copy will be retained by the field sampler.
- Proper documentation will be maintained for shipments by common carrier.

### **Sample Shipment Procedures**

The following procedures will be followed when shipping samples for laboratory analysis:

- Samples requiring cooling to 4°C will be promptly chilled with ice or Blue Ice and will be packaged in an insulated cooler for transport to the laboratory. A temperature blank will be included in each cooler to be used as a temperature indicator. Each temperature blank will be clearly identified by the field sampling team. Ice will be sealed in containers to prevent leakage of water. Samples will not be frozen.
- Only shipping containers that meet all applicable state and Federal standards for safe shipment will be used.
- Shipping containers will be sealed with nylon strapping tape, custody seals will be signed, dated, and affixed, in a manner that will allow the receiver to quickly identify any tampering that may have occurred during transport to the laboratory.
- The field chain-of-custody document will be placed inside the shipping container in a sealed plastic envelope.
- Shipment will be made by a public courier. After samples have been taken, they will be sent to the laboratory within 24 hours.

## **Field Documentation Responsibilities**

It will be the responsibility of the B&R Environmental FOL to secure all documents produced in the field (e.g., sampling logs, calibration forms) at the end of each work day. A copy of all forms used during field activities are included in Appendix A.

At the completion of field activities, the B&R Environmental FOL will send to the B&R Environmental Project Manager all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheets, daily logs, etc. The B&R Environmental Project Manager will ensure that these material are entered into the B&R Environmental document control system in accordance with appropriate administrative guidelines.

Changes in project operating procedures may be necessary as a result of changed field conditions or unanticipated events. A summary of the sequence of events associated with field changes is as follows:

- The B&R Environmental FOL notifies the B&R Environmental Project Manager of the need for the change.
- If necessary, the B&R Environmental Project Manager will discuss the change with the pertinent individuals (e.g., Navy Remedial Project Manager, B&R Environmental Quality Assurance Manager) and will provide a verbal approval or denial to the B&R Environmental FOL for the proposed change.
- The B&R Environmental FOL will document the change on a Task Modification Request form and forward the form to the B&R Environmental Project Manager at the earliest convenient time (e.g., end of the work week).
- The B&R Environmental Project Manager will sign the form and distribute copies to the Navy Remedial Project Manager (RPM), B&R Environmental Quality Assurance Manager, B&R Environmental FOL, and project file.
- A copy of the completed Task Modification Request form will be attached to the field copy of the affected document.

The possession of all records will be documented; however, only the B&R Environmental FOL or designee may remove field data from the site for reduction and evaluation.

## **Laboratory Sample Custody**

To ensure the integrity of a sample from collection through analysis, it is necessary to have an accurate, written record that traces the possession and handling of the sample. This documentation is referred to as the sample chain-of-custody.

A sample is under custody if:

- The sample is in the physical possession of an authorized person.
- The sample is in view of an authorized person after being in his/her possession.
- The sample is placed in a secure area by an authorized person after being in his/her possession.
- The sample is in a secure area, restricted to authorized personnel only.

Sample custody during collection and shipping is discussed in B&R Environmental SOP SA-6.1, which is included in Appendix B. Laboratory sample custody is discussed in the following sections.

When samples are received, the shipping manifest is signed and dated to acknowledge sample receipt. The sample custodian must examine the shipping containers and verify that the correct number of containers was received. The shipping containers are then opened and the enclosed sample paperwork is removed. Samples are removed from the shipping containers and the bottle condition and cooler temperature must be noted. The information on the chain-of-custody, the airbill, the containers, and the laboratory request is reviewed to note any discrepancies.

All samples received by the laboratory must be stored at 4°C until analysis. Laboratory holding times are specified by the contract and are presented in Table 4-2.

## **4.2 QUALITY ASSURANCE OBJECTIVES**

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide environmental monitoring data of known and acceptable quality. Specific procedures to be used for sampling, chain-of-custody, calibration of field instruments, laboratory analysis, reporting, internal quality control, audits, preventative maintenance, and corrective actions are described in later sections of this plan.

#### **4.2.1      Quality Control Samples**

The following QC samples will be collected and analyzed as part of the groundwater monitoring at DRMO. These samples will be used to aid in evaluation of sample collection and handling procedures being employed during groundwater sampling events.

#### **Field Duplicates**

Field duplicates are two samples collected: (1) independently at a sampling location in the case of groundwater or surface water, or (2) a single sample split into two portions in the case of soil or sediment. Duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. A minimum of one duplicate sample will be collected during each sample event. Duplicates will be analyzed for the same parameters in the laboratory and will be labeled so as to make the identity of the duplicate unknown to the laboratory.

#### **Trip Blanks**

Trip blanks are samples which originate from analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic analysis samples (such as TCL VOCs). One trip blank will be collected during each sample event. Trip blanks are only analyzed for the volatile constituents that are being shipped in a given cooler.

### **4.3            CALIBRATION PROCEDURES AND FREQUENCY**

Instruments used in the field and in the laboratory will be calibrated according to the procedures described below. Several monitoring instruments will be used during field activities, including:

- Electronic water-level meter
- HNu/OVA organic vapor detector

The electronic water-level meter will be calibrated prior to field use and periodically at the discretion of the B&R Environmental FOL. The remaining instrument will be calibrated daily or according to the manufacturer's operating manual.

Calibration will be documented on an Equipment Calibration Log (Appendix A). During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective

parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the defective parts are repaired or replaced.

Calibration of equipment at the analytical laboratory will comply with the specified analytical method.

#### **4.4 INTERNAL QUALITY CONTROL CHECKS**

Quality control samples generated by B&R Environmental will include the collection of field duplicates and trip blanks. See Table 4-2 for the required number of sample duplicates.

There are two types of quality assurance mechanisms used to ensure the production of analytical data of known and documented quality. The internal quality control procedures for the analytical services are specified under the Naval Facilities Engineering Services Center (NFESC) guidelines and Table 4-2. These specifications include the types of control samples required (sample spikes, surrogate spikes, controls, and blanks), the frequency of each control, the compounds to be used for sample spikes and surrogate spikes, and the quality control acceptance criteria. It will be the laboratory's responsibility to document, in each package, that both initial and ongoing instrument and analytical QC criteria are met. This documentation will be included in the data packages generated by the contract laboratory.

Analytical results of field-collected quality control samples will also be compared to acceptance criteria, and documentation will be performed showing that criteria have been met. Any samples in nonconformance with the QC criteria will be identified and reanalyzed by the laboratory, if possible. The following procedures will be employed for the samples:

- Proper storage of samples.
- Use of qualified and/or certified technicians.
- Use of calibrated equipment.
- Formal independent confirmation of all computation and reduction of laboratory data and results.
- Use of standardized test procedures.

- Inclusion of replicate samples at a frequency of one replicate per 10 samples or one per sample matrix if less than 10 samples are collected.

#### **4.5 PERFORMANCE AND SYSTEM AUDITS**

System audits will be performed as appropriate, to assure that the work is being implemented in accordance with the approved project SOPs and in an overall satisfactory manner.

- The B&R Environmental FOL will supervise and check on a daily basis that the monitoring wells are installed and developed correctly, field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and the field work is accurately and neatly documented.
- A B&R Environmental Data Validator will review (on a timely basis) the data packages submitted by the laboratory. This Data Validator will check that the data was obtained through the approved methodology, that the appropriate level of QC effort and reporting was conducted, that holding times were met, and that the results are in conformance with the QC criteria. On the basis of these factors, the B&R Environmental Data Validator will evaluate the data quality and limitations.
- The B&R Environmental Project Manager will oversee the B&R Environmental FOL and Data Validator, and check that management of the acquired data proceeds in an organized and expeditious manner.
- System audits for the laboratory are conducted by NFESC on a regular basis as required.
- A formal audit of the field sampling procedures may be conducted in addition to the auditing that is an inherent part of the daily project activities.
- The auditors will check that sample collection, sample handling, decontamination protocols, and instrument calibration and use are in accordance with the approved project SOPs. The auditors will also check that the field documentation logs and chain-of-custody forms are being filled out properly.

The subcontracted analytical laboratory must be approved by NFESC, be eligible to perform the required analysis under NFESC protocols, and must have site-specific approval prior to commencement of work.

#### **4.6 PREVENTATIVE MAINTENANCE**

B&R Environmental has established a program for the maintenance of field equipment to ensure the availability of equipment in good working order when and where it is needed. This program consists of the following elements.:

- The B&R Environmental Equipment Manager keeps an inventory of the equipment in terms of items (model and serial number) quantity and condition. Each item of equipment is signed out when in use, and its operating condition and cleanliness checked upon return.
- The B&R Environmental Equipment Manager conducts routine checks on the status of equipment and is responsible for the stocking of spare parts and equipment readiness.
- The B&R Environmental Equipment Manager maintains the equipment manual library and trains field personnel in the proper use and care of equipment.
- The B&R Environmental FOL is responsible for working with the B&R Environmental Equipment Manager to make sure that the equipment is tested, cleaned, charged, and calibrated in accordance with the manufacturer's instructions and B&R Environmental's SOPs before being taken to the job site and during field activities.

#### **4.7 CORRECTIVE ACTION**

The QA program will enable problems to be identified, controlled, and corrected. Potential problems may involve nonconformance with the SOPs and/or analytical procedures established for the project or other unforeseen difficulties. Any person identifying an unacceptable condition will notify the B&R Environmental Project Manager. The B&R Environmental Project Manager, with the assistance of the B&R Environmental Project QA/QC Officer, will be responsible for developing and initiating appropriate corrective action and verifying that the correction action has been effective. Corrective actions may include the following: re-sampling and/or reanalysis of sample, amending or adjusting project procedures. If warranted by the severity of the problem (for example, if a change in the approved work plan is required), the Navy will be notified in writing and their approval will be obtained prior to implementing any change. Minor changes will be documented to the main file by the B&R Environmental Project Manager. Additional work that is dependent on a non-conforming activity will not be performed until the problem has been eliminated.

The laboratory maintains an internal closed-loop corrective action system that operates under the direction of the laboratory's QA Coordinator.



## **5.0 MONITORING CRITERIA AND DATA EVALUATION**

This section contains a discussion of the regulatory criteria which will be used for evaluation of the analytical results to determine compliance. A discussion of the data evaluation procedures to be performed on the analytical results obtained during the groundwater monitoring activities is also included. In addition, this section summarizes the format for reporting the analytical results obtained from the groundwater monitoring activities.

### **5.1 MONITORING CRITERIA**

The Connecticut Remediation Standard Regulations (RSRs) require that all groundwater plumes be remediated to attain either a.) the Surface Water Protection Criteria (SWPCs) and the Volatilization Criteria, or b.) the background concentration for each substance in the plume (CTDEP, December 1995). Accordingly, the primary monitoring criteria will be the site-specific SWPCs developed for the DRMO (B&R Environmental, September 1997) as well as the standard SWPCs and Volatilization Criteria promulgated by the CTDEP.

These monitoring criteria are defined as follows:

- SWPCs (site-specific and CTDEP) are groundwater standards based on the protection of human health and aquatic life. These standards are applicable to the remediation of groundwater which discharges to a surface water body by reduction of each substance to a concentration equal to or less than the surface water protection criteria (CTDEP, December 1995).
- CTDEP Volatilization Criteria are groundwater standards applicable to all groundwater polluted with a volatile organic substance within 15 feet of the ground surface or a building. If the groundwater is below a building used solely for industrial or commercial activity, the applicable industrial/commercial volatilization criteria is used for evaluation of the groundwater (CTDEP, December 1995).

As a result of discussions between the Navy, U.S. EPA, and CTDEP, Connecticut's GB Pollutant Mobility Criteria have been established as not applicable since ground elevation at the DRMO is below the high seasonal water table (B&R Environmental, September 1997). However, the groundwater analytical results obtained during the monitoring will initially be compared to these criteria to insure that groundwater is not adversely impacted by contaminants in the DRMO soil.

In addition, the Federal Ambient Water Quality Criteria (AWQCs) and the Connecticut Water Quality Standards (WQSS) will be used as secondary monitoring criteria.

- Federal AWQCs are non enforceable regulatory guidelines and are of primary utility in evaluating the potential for toxic effects in aquatic organisms. They may also be used to identify the potential for human health risks. AWQCs are available for the acute and chronic toxic effects in both freshwater and saltwater aquatic life, the adverse human health effects from ingestion of both water (2 liters per day) and aquatic organisms (6.5 grams per day), and from ingestion of organisms alone. This report will focus on the human health criteria for ingestion of organisms only and the chronic toxic effects in saltwater aquatic life.
- Connecticut WQSS are intended to protect high quality waters from degradation from waste discharges water quality criteria for surface water is similar to the Federal AWQCs and will be used to compare the analytical results obtained from the monitoring activities.

The groundwater analytical results obtained during the monitoring will be compared to the Federal AWQCs and Connecticut WQSS developed for chronic (long-term) exposure of aquatic receptors in saltwater. In addition, groundwater analytical results will also be compared to the Federal and State human health criteria for consumption of organisms since recreational fishing may occur in the Thames River. Since the Thames River is not a source of drinking water, no human health criteria for the ingestion of water will be used.

## **5.2 POTENTIAL CHEMICALS OF CONCERN**

### **5.2.1 Surface Water Protection COCs**

The Feasibility Study (FS) (B&R Environmental, September 1997) identified potential soil COCs for the protection of the Thames River water. This was done by back-calculating soil chemical concentrations which could result in exceedances of site-specific SWPCs as a result of migration to groundwater and by comparing these calculated concentrations to the maximum concentrations detected in soil. The following is a list of these potential COCs:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzoic Acid
- 4,4'-DDD
- Aroclors 1254 and 1260
- Hexachlorobiphenyl
- Barium
- Cadmium
- Chromium
- Silver
- Zinc

These chemicals will be monitored during the life of the groundwater monitoring program until it is determined that the DRMO is not impacting the surface water.

Maximum detected groundwater concentrations were also compared to the site-specific and CTDEP SWPCs. Although none of these concentrations exceeded the site-specific SWPCs, the following chemicals were detected at maximum concentrations which exceeded the CTDEP SWPCs and are therefore identified as potential COCs:

- Arsenic
- Copper
- Lead
- Zinc

These chemicals will be monitored for the first year of quarterly sampling to verify that they are not affecting the Thames River water.

### 5.2.2 Pollutant Mobility COCs

Although, as discussed in Section 5.1, Connecticut's pollutant mobility criteria do not apply at the DRMO, the following chemicals have been detected above their respective GB Pollutant Mobility Criteria:

- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloroethane
- 1,2-Dichloroethene (total)
- Trichloroethene
- Vinyl Chloride
- Benzo(a)anthracene
- Benzo(a)pyrene
- Fluoranthene
- Fluorene
- Naphthalene
- Phenanthrene
- Pyrene
- Heptachlor Epoxide
- Aroclors 1254 and 1260

- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Bis(2-ethylhexyl)phthalate
- Hexachlorobiphenyl
- Cadmium
- Lead

These chemicals will be monitored for the first year on a quarterly basis to insure that they are not adversely impacting the groundwater at the DRMO by migrating from the soil.

### 5.2.3 Chemicals To Be Evaluated

By combining the above lists of potential COCs, the following initial list of chemicals to be evaluated during monitoring was obtained:

- |                              |                              |            |
|------------------------------|------------------------------|------------|
| • 1,1,2,2-Tetrachloroethane  | • Bis(2-ethylhexyl)phthalate | • 4,4'-DDD |
| • 1,2-Dichloroethane         | • Fluoranthene               | • Arsenic  |
| • 1,2-Dichloroethene (total) | • Fluorene                   | • Barium   |
| • Trichloroethene            | • Naphthalene                | • Cadmium  |
| • Vinyl Chloride             | • Phenantrene                | • Chromium |
| • Benzo(a)anthracene         | • Pyrene                     | • Copper   |
| • Benzo(a)pyrene             | • Heptachlor Epoxide         | • Lead     |
| • Benzo(b)fluoranthene       | • Aroclors 1254 & 1260       | • Silver   |
| • Benzo(k)fluoranthene       | • Hexachlorobiphenyl         | • Zinc     |
| • Benzoic Acid               |                              |            |

The above list is initial and subject to changes based upon the results of groundwater monitoring. Analytical detection limits for the above chemicals are listed in Appendix E.

## 5.3 DATA EVALUATION

The objective of this Groundwater Monitoring Plan is to provide the approach for long-term monitoring to determine whether contamination is migrating through the soil beneath the cap, into the groundwater, and ultimately discharging to the Thames River at concentrations which may adversely impact human and ecological receptors. To achieve this objective groundwater monitoring will be conducted. The first year of sampling will consist of quarterly sampling events. The groundwater samples obtained during this first year will be analyzed for full TCL/TAL parameters. However, only the potential COCs identified in Section 5.2 will be compared to the criteria discussed in Section 5.1. A cursory review of the remaining chemicals will be conducted to confirm that these constituents are not impacting the surface water. Figure 5-1

outlines the evaluation and decision sequence to be conducted during the groundwater monitoring activities at the DRMO.

The analytical data obtained from the seven downgradient wells will be compared to the three upgradient well data to determine if any of the compounds detected are a result of known site contaminants. In addition, the groundwater analytical data obtained from the downgradient monitoring wells at the DRMO will be evaluated against the criteria established in Section 5.1 and compared to previous sampling rounds.

Table 5-1 presents the background concentrations, site-specific SWPCs, and CTDEP SWPCs and Volatilization Criteria for the chemicals to be evaluated as established in Section 5.2.

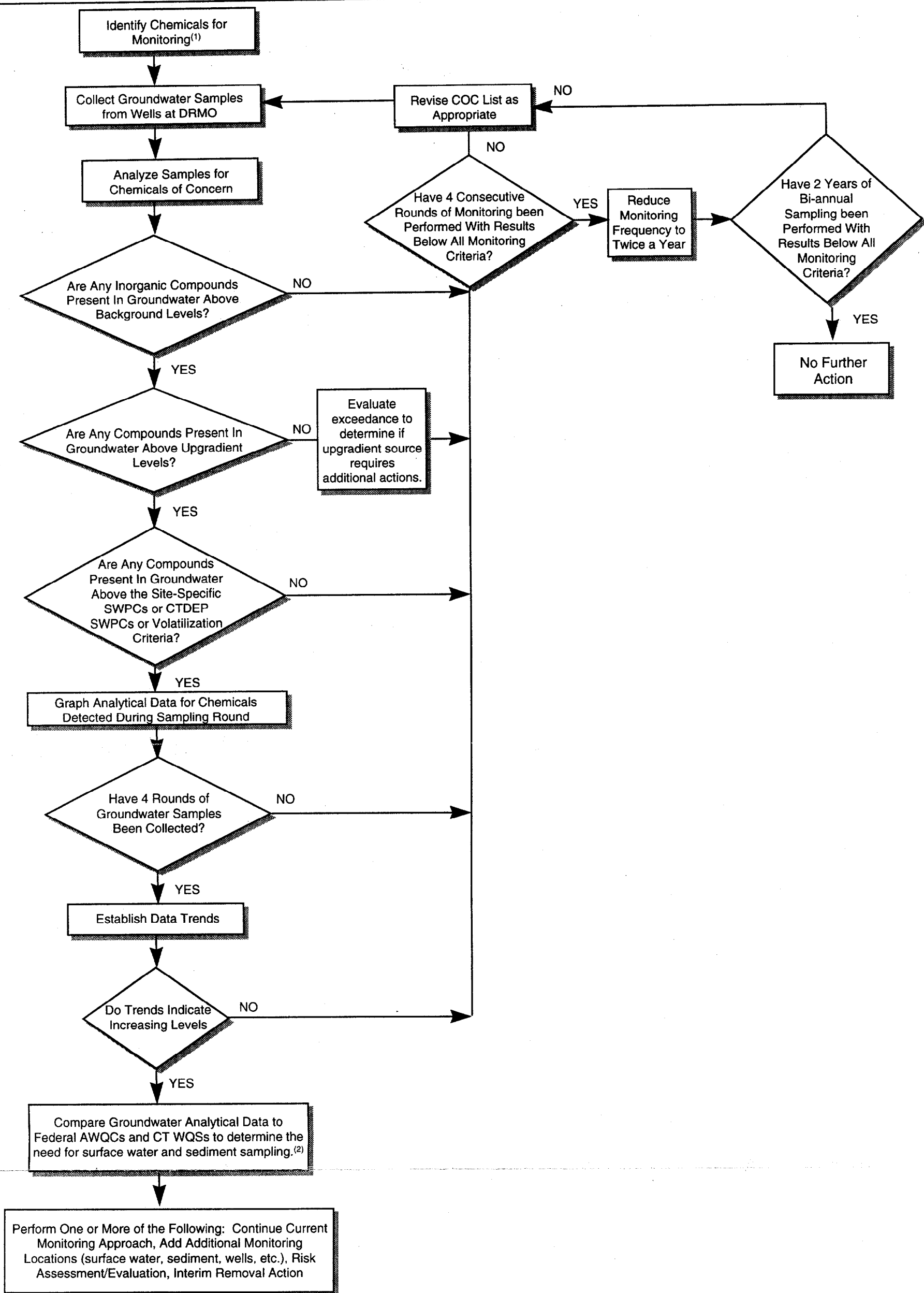
Compliance with the SWPCs (site-specific or CTDEP) for a given compound in a groundwater plume is achieved when sampling locations are representative of the plume and:

- The average concentration of the compound in the plume is equal to or less than the applicable SWPC for at least four (4) consecutive quarterly sampling periods,
- The concentration of the compound in the plume immediately upgradient of the point at which such groundwater discharges to the receiving surface water body is equal to or less than the applicable SWPC, provided that the areal extent of the plume is not increasing over time and that, except for seasonal variations, the concentration of the compound in the plume is not increasing over time, except as a result of natural attenuation.

Compliance with the CTDEP Volatilization Criterion for a given compound in groundwater is achieved when the sampling locations are representative of the plume and:

- The ninety-five percent upper confidence level (UCL) of the arithmetic mean of all sample results from such locations is equal to or less than the applicable Volatilization Criterion for at least four (4) consecutive quarterly sampling periods, and
- The result of no single sample exceeds two times the applicable Volatilization Criterion, or
- The results of all laboratory analyses of samples for such substance are equal to or less than the Volatilization Criterion.

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- (1) Initially evaluate soil contaminants which exceed the CTDEP Pollutant Mobility Criteria for GB classified groundwater. Evaluate chemicals in groundwater which exceed the site-specific Surface Water Protection Criteria (SWPCs) and Volatilization Criteria. Also include COCs identified in the Site 6 DRMO Feasibility Study and PCBs.
- (2) Surface water samples will be compared to the Federal AWQCs and Connecticut WQs; sediment samples will be compared to NOAA ERLs/ERMs.

FIGURE 5-1

**GROUNDWATER MONITORING PLAN DECISION DIAGRAM**  
**DRMO**  
**NSB-NLON, GROTON, CONNECTICUT**



**Brown & Root Environmental**

0150810Z

TABLE 5-1

**MONITORING CRITERIA  
GROUNDWATER MONITORING PLAN  
DRMO - NSB-NLON, GROTON, CONNECTICUT**

Chemical	Background Concentration (1)	Monitoring Criteria		
		Site-Specific SWPC(2)	CTDEP SWPC(3)	CTDEP Volatilization(4)
VOCs (µg/L):				
1,1,2,2-Tetrachloroethane	NA	1,100	110	100
1,2-Dichloroethane	NA	29,700	2,970	90
1,2-Dichloroethene (total)	NA	NA	NA	NA
Trichloroethene	NA	23,400	2,340	540
Vinyl Chloride	NA	157,500	15,750	2
SVOCs (µg/L):				
Benzo(a)anthracene	NA	3.0	0.3	NA
Benzo(a)pyrene	NA	3.0	0.3	NA
Benzo(b)fluoranthene	NA	3.0	0.3	NA
Benzo(k)fluoranthene	NA	3.0	0.3	NA
Benzoic Acid	NA	NA	NA	NA
Bis(2-ethylhexyl)phthalate	NA	590	59	NA
Fluoranthene	NA	37,000	3,700	NA
Fluorene	NA	1,400,000	140,000	NA
Naphthalene	NA	NA	NA	NA
Phenanthrene	NA	0.77	0.077	NA
Pyrene	NA	1,100,000	110,000	NA
Pesticides/PCBs (µg/L):				
Heptachlor Epoxide	NA	0.5	0.05	NA
Aroclors 1254 & 1260	NA	5.0	0.5	NA
Hexachlorobiphenyl	NA	5.0	0.5	NA
4,4'-DDD	NA	NA	NA	NA
Inorganics (µg/L):				
Arsenic	3.6	40	4	NA
Barium	NA	NA	NA	NA
Cadmium	0.24(5)	60	6	NA
Chromium	21.5	1,100	110	NA
Copper	25.6	480	48	NA
Lead	17.5	130	13	NA
Silver	NA	120	12	NA
Zinc	31.3	1,230	123	NA

**NOTES:**

NA Not Available

(1) Highest value detected among all background 0-4 feet soil samples collected in April 1993.

(2) Surface Water Protection Criteria for substances in groundwater, using a site-specific dilution factor of 100 (B&amp;R Environmental, September 1997).

(3) Surface Water Protection Criteria for Substances in Groundwater, using a dilution factor of 10 (CTDEP, December 1995).

(4) Industrial/commercial volatilization criteria for groundwater.

(5) Half of the highest detection from among all the background soil samples collected in April 1993.



In addition, as discussed in Section 5.1, the results will also be compared to Federal AWQCs and Connecticut WQSs for second-tier evaluation purposes only. Table 5-2 lists the aquatic life and human health saltwater chronic Federal AWQCs and Connecticut WQSs for the chemicals identified in Section 5.2.

#### **5.4 COMPARISON**

The groundwater monitoring is designed to determine 1.) the effectiveness of the existing asphalt/GCL cap at the DRMO in preventing further migration of chemicals to the groundwater and ultimately to the Thames River, 2.) the effectiveness of the remediation taken to eliminate health risks, and 3.) whether the SWPCs and Volatilization Criteria listed on Table 5-1 have been met, and 4.) whether the groundwater plume interferes with any existing use of the groundwater.

To determine the effectiveness of the cap, the sampling results from the upgradient wells will be compared to the results from the downgradient wells. Proposed well 6MW9S, located immediately upgradient of the capped area of the DRMO, and existing wells 6MW6S and 6MW6D located east of the site will be used to determine upgradient groundwater conditions. This analytical data will be compared to the results of the groundwater data from the five existing (6MW1S, 6MW2S, 6MW2D, 6MW3S, and 6MW3D) and two new (6MW10S and 6MW10D) downgradient wells to determine if the DRMO is adding contamination to the groundwater before entering the Thames River and thus determine the effectiveness of the cap. Additionally, inorganic compounds concentrations will be compared to background levels for NSB-NLON, as shown on Table 5-1. Subsequently, analytical results obtained from the monitoring wells will be compared to the site specific SWPCs and CTDEP SWPCs and Volatilization Criteria listed on Table 5-1 to verify that chemicals are not migrating from the site at concentrations above criteria. The goal of the monitoring program is to attain surface water protection requirements for those contaminants. The analytical results will also be compared to the Federal AWQCs and Connecticut WQSs listed on Table 5-2 to screen contaminants and aid in the decision-making process. No existing uses of the groundwater have been identified in the vicinity of the DRMO, therefore the groundwater plume does not interfere with any existing uses.

TABLE 5-2

**SURFACE WATER COMPARISON CRITERIA  
GROUNDWATER MONITORING PROGRAM  
DRMO - NSB-NLON, GROTON, CONNECTICUT**

Chemical	Federal AWQCs <sup>(1)</sup>		Connecticut WQSS <sup>(2)</sup>	
	Aquatic Life <sup>(3)</sup>	Human Health <sup>(4)</sup>	Aquatic Life <sup>(5)</sup>	Human Health <sup>(4)</sup>
<b>VOCs (µg/L):</b>				
1,1,2,2-Tetrachloroethane	NA	11	NA	11
1,2-Dichloroethane	NA	99	NA	99
1,2-Dichloroethene (total)	NA	NA	NA	NA
Trichloroethene	NA	81	NA	81
Vinyl Chloride	NA	525	NA	525
<b>SVOCs (µg/L):</b>				
Benzo(a)anthracene	NA	0.0311	NA	0.031
Benzo(a)pyrene	NA	0.0311	NA	0.031
Benzo(b)fluoranthene	NA	0.0311	NA	0.031
Benzo(k)fluoranthene	NA	0.0311	NA	0.031
Benzoic Acid	NA	NA	NA	NA
Bis(2-ethylhexyl)phthalate	NA	5.9	NA	5.9
Fluoranthene	NA	370	NA	370
Fluorene	NA	14,000	NA	14,000
Naphthalene	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	0.031
Pyrene	NA	11,000	NA	11,000
<b>Pesticides/PCBs (µg/L):</b>				
Heptachlor Epoxide	0.0036	0.00011	0.0008	0.00011
Aroclors 1254 & 1260	0.03	0.000045	0.03	0.000045
Hexachlorobiphenyl	0.03	0.000045	0.03	0.000045
4,4'-DDD	NA	0.00084	NA	0.00084
<b>Inorganics (µg/L):</b>				
Arsenic	36	0.14	36	0.14
Barium	NA	NA	NA	NA
Cadmium	9.3	NA	9.3	170
Chromium	50	NA	50	3,400
Copper	2.4	NA	2.9	NA
Lead	8.1	NA	8.5	NA
Silver	1.9 <sup>(7)</sup>	NA	2.3 <sup>(8)</sup>	65,000
Zinc	81	NA	86	NA

**NOTES:**

NA Not Available

- (1) Ambient Water Quality Criteria (U.S. EPA, 1986) for comparison only.
- (2) Connecticut Water Quality Standards (CTDEP, May, 1992).
- (3) Criterion for saltwater at a continuous concentration.
- (4) Criterion for consumption of organisms only.
- (5) Criterion for saltwater at a chronic concentration.
- (6) Criterion applies to the dissolved fraction.
- (7) Criterion for saltwater at a maximum concentration
- (8) Criterion for saltwater at an acute concentration

The results of each round of monitoring will be recorded in a database and plotted on a time versus concentration graph to indicate trends. In addition, after four rounds of groundwater monitoring have been completed, statistical analysis of results may be performed, if appropriate. Statistical methods are performed to evaluate the quality and validity of a data set, which eventually aids in the decision making process. Specific statistical tests may be used to 1.) identify potential outliers in the data set, 2.) measure the dispersion of the data set, and 3.) evaluate concentration trends over time.

Statistical tests will be utilized for the evaluation of the cap installed at the DRMO. It is crucial to show that the DRMO is not adding further contamination to the groundwater than already exists in the upgradient wells. When four rounds of groundwater data become available, a statistical comparison of upgradient and downgradient sample means at the 95-percent confidence level should adequately demonstrate the success or failure of the remedial technology. This methodology is consistent with the U.S. EPA's Addendum to the Statistical Guidance Document for Groundwater Monitoring (1992). Statistics will only be performed for analytes which are detected in the downgradient wells.

Prior to performing statistical comparison between upgradient and downgradient analyte concentrations, the Shapiro and Wilk w-test will be performed for each analyte in order to determine if the data are normally or lognormally distributed. For analytes demonstrating the same distribution in the upgradient and downgradient wells, the parametric t-test will be employed for the mean comparison. If the w-test shows that the data do not adequately fit a normal or lognormal distribution, the nonparametric Wilcoxon Rank-Sum test will be employed. Both parametric and nonparametric tests will be run at the 95-percent confidence level. Corrections for seasonality should not be necessary since the geographic area containing the upgradient and downgradient wells is small enough such that seasonal fluctuations should affect all wells in a similar manner. Plots may be constructed using the moving averages of the upgradient and downgradient wells in order to support assumptions and conclusions.

After the first year of quarterly sampling is completed, the trends in the data set will be evaluated to determine if chemical concentrations are increasing or decreasing. The results will be evaluated to determine if a change in the proposed monitoring regime is necessary or a response action is warranted. Once this baseline has been established, the monitoring program will be evaluated and modified as necessary to include additional sample points and/or media. Increasing trends or exceedances of monitoring criteria will prompt additional sampling (i.e., surface water/sediment sampling, additional groundwater sampling locations, etc.) and evaluation. If it is determined that there is a trend of increasing chemical concentrations in groundwater, the analytical data will be compared to the Federal AWQCs and Connecticut WQSS to determine if it is necessary to perform surface water and sediment sampling, add additional monitoring locations, or continue with the current monitoring approach. Also, based on an

increasing data trend, it will be determined if a risk assessment/evaluation or interim removal action is necessary.

If the data trends do not indicate increasing levels, the groundwater analytical data will be evaluated against the action criteria to determine the number of rounds exceeding the criteria. Four rounds of groundwater with no exceedances of the action criteria would result in the reduction of the monitoring frequency to bi-annual sampling (twice a year). The exceedance of the action criteria during any round within a yearly sampling event would result in the revision of the list of chemicals to be evaluated and the continued monitoring of the groundwater.

After conducting two years of bi-annual sampling with no exceedances of action criteria, the DRMO site would be recommended for No Further Action. If during the bi-annual sampling, action criteria were exceeded, data trends will be evaluated as discussed previously and the need for additional action will be determined.

## **5.5 REPORTING CRITERIA**

Following the monitoring well and pump installation and sampling activities, a quarterly (or other monitoring frequency as determined) report will be completed to present the results and findings of the groundwater monitoring at the DRMO. This report will contain the following information:

- Introduction
- Background and Previous Investigation Summary
- Sampling Locations and Methods Employed
- Results of Sampling
- Comparison of Analytical Data with Monitoring Criteria
- Recommendations and Conclusions

## REFERENCES

Atlantic (Atlantic Environmental Services, Inc.), August 1992. Phase I Remedial Investigation Naval Submarine Base - New London, Groton, Connecticut. Colchester, CT.

Atlantic (Atlantic Environmental Services, Inc.), March 1995. Action Memorandum for the Defense Reutilization and Marketing Office and the Spent Acid Storage and Disposal Area, Installation Restoration Program. Colchester, CT.

Atlantic (Atlantic Environmental Services, Inc.), April 1995. Background Concentrations of Inorganics in Soil. Installation Restoration Program, Naval Submarine Base - New London, Groton, Connecticut.

Brown & Root Environmental, March 1996. Phase II Remedial Investigation for Naval Submarine Base, New London, Groton, Connecticut. Wayne, PA.

CT (State of Connecticut), 1995. "Standards for Quality of Public Drinking Water." Title 19, Regulation 19-13, Section 19-13-B102.

CTDEP (State of Connecticut Department of Environmental Protection), December 1995. "Remediation Standard Regulations." Bureau of Water Management, Permitting, Enforcement and Remediation Division, Hartford, Connecticut.

OHM (OHM Remediation Services Corporation), September 1995. Final Report for Interim Remedial Action, Site 6, Naval Submarine Base, New London, Groton, Connecticut. Hopkinton, MA

SCS (Soil Conservation Service), 1983. Soil Survey of New London County Connecticut.

USGS (United States Geological Survey), 1960. Geologic Map of the Uncasville Quadrangle, Connecticut, Surficial Geology.

USGS (United States Geological Survey), 1967. Bedrock Geologic Map of the Uncasville Quadrangle, New London County, Connecticut.

**APPENDIX A**  
**FIELD INVESTIGATION FORMS**



WELL I.D.: \_\_\_\_\_

DATE: \_\_\_\_\_

[illegible]



# MONITORING WELL SHEET

PROJECT \_\_\_\_\_ LOCATION \_\_\_\_\_  
 PROJECT NO. \_\_\_\_\_ BORING \_\_\_\_\_  
 ELEVATION \_\_\_\_\_ DATE \_\_\_\_\_  
 FIELD GEOLOGIST \_\_\_\_\_

DRILLER \_\_\_\_\_  
 DRILLING \_\_\_\_\_  
 METHOD \_\_\_\_\_  
 DEVELOPMENT \_\_\_\_\_  
 METHOD \_\_\_\_\_

Ground Elevation \_\_\_\_\_

Flush mount surface casing with lock \_\_\_\_\_

ELEVATION TOP OF RISER: \_\_\_\_\_

TYPE OF SURFACE SEAL: \_\_\_\_\_

TYPE OF PROTECTIVE CASING: \_\_\_\_\_

I.D. OF PROTECTIVE CASING: \_\_\_\_\_

DIAMETER OF HOLE: \_\_\_\_\_

TYPE OF RISER PIPE: \_\_\_\_\_

RISER PIPE I.D.: \_\_\_\_\_

TYPE OF BACKFILL/SEAL: \_\_\_\_\_

DEPTH/ELEVATION TOP OF SAND: \_\_\_\_\_

DEPTH/ELEVATION TOP OF SCREEN: \_\_\_\_\_

TYPE OF SCREEN: \_\_\_\_\_

SLOT SIZE x LENGTH: \_\_\_\_\_

TYPE OF SAND PACK: \_\_\_\_\_

DIAMETER OF HOLE IN BEDROCK: \_\_\_\_\_

DEPTH/ELEVATION BOTTOM OF SCREEN: \_\_\_\_\_

DEPTH/ELEVATION BOTTOM OF SAND: \_\_\_\_\_

DEPTH/ELEVATION BOTTOM OF HOLE: \_\_\_\_\_

BACKFILL MATERIAL BELOW SAND: \_\_\_\_\_





# Brown & Root Environmental

## WELL DEVELOPMENT SHEET

PROJECT NAME: \_\_\_\_\_ SITE/LOCATION: \_\_\_\_\_  
PROJECT NUMBER: \_\_\_\_\_ MEASURING DEVICE: \_\_\_\_\_  
PERSONNEL: \_\_\_\_\_ ADJUSTMENT FACTOR: \_\_\_\_\_  
WEATHER: \_\_\_\_\_ DATE: \_\_\_\_\_  
REMARKS: \_\_\_\_\_ WELL NO.: \_\_\_\_\_

☐ Domestic Well ☐ Monitoring Well  
☐ Other Well \_\_\_\_\_

Static Water Level: \_\_\_\_\_  
Total Depth: \_\_\_\_\_  
One Casing Volume: \_\_\_\_\_

Method: \_\_\_\_\_  
Start Time: \_\_\_\_\_  
Complete Time: \_\_\_\_\_

Approx Volume	Time	pH	Temp (°C)	Turbidity	Color	Specific Conductance	Dissolved Oxygen

NOTE: All measurements to nearest 0.01 foot measured from top of well riser pipe unless otherwise noted

Additional Comments \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Signature \_\_\_\_\_

Page \_\_\_\_\_ of \_\_\_\_\_

[illegible]

Signature(s): \_\_\_\_\_

# GROUNDWATER SAMPLE LOG SHEET

Page of

Project Site Name: _____	Sample ID No.: _____
Project No.: _____	Sample Location: _____
<input type="checkbox"/> Domestic Well Data <input type="checkbox"/> Monitoring Well Data <input type="checkbox"/> Other Well Type: _____ <input type="checkbox"/> QA Sample Type: _____	Sampled By: _____ C.O.C. No.: _____

Sampling Data								
Date: _____	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD
Time: _____								
Method: _____								

Purge Data								
Date: _____	Volume	pH	S.C.	Temp.(°C)	Turbidity	Color	TBD	TBD
Method: _____	Initial							
Monitor Reading (ppm):	1							
Well Casing Dia. & Material Type:	2							
	3							
Total Well Depth (TD):	4							
Static Water Level (WL):	5							
TD-WL (ft.) =								
One Casing Volume: (gal/L)								
Start Purge (hrs.):								
End Purge (hrs.):								
Total Purge Time (min):								
Total Amount Purged (gal/L):								

[illegible]

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

TBD: To Be Determined



## EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME / MODEL : \_\_\_\_\_

JOB NAME : \_\_\_\_\_

MANUFACTURER : \_\_\_\_\_

JOB NUMBER : \_\_\_\_\_

[illegible]

Well I.D. #:

## CHAIN OF CUSTODY RECORD

[illegible]

## **APPENDIX B**

### **STANDARD OPERATING PROCEDURES (SOPs)**

#### **Geology/Hydrogeology**

- GH-1.2      Evaluation of Existing Monitoring Wells and Water Level Measurement**
- GH-1.3      Soil and Rock Drilling Methods**
- GH-1.5      Borehole and Sample Logging**
- GH-2.8      Groundwater Monitoring Point Installation**

#### **Sampling**

- SA-1.1      Groundwater Sample Acquisition and Onsite Water Quality Testing**
- SA-6.1      Non-Radiological Sample Handling**
- SA-6.3      Field Documentation**

#### **Support Field Methods**

- SA-7.1      Decontamination of Field Equipment and Waste Handling**



**BROWN & ROOT ENVIRONMENTAL**

# STANDARD OPERATING PROCEDURES

Number  
GH-1.2

Page  
1 of 9

Effective Date  
03/01/96

Revision  
0

Applicability  
B&R Environmental, NE

Prepared  
Earth Sciences Department

Subject      **EVALUATION OF EXISTING MONITORING WELLS  
AND WATER LEVEL MEASUREMENT**

Approved  
D. Senovich

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## **1.0 PURPOSE**

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating existing monitoring wells, and determining water level measurements.

## **2.0 SCOPE**

The procedures described herein are applicable to all existing monitoring wells and, for the most part, are independent of construction materials and methods.

## **3.0 GLOSSARY**

Hydraulic Head - The height to which water will rise in a well.

Water Table - A surface in an unconfined aquifer where groundwater pressure is equal to atmospheric pressure (i.e., the pressure head is zero).

## **4.0 RESPONSIBILITIES**

Site Geologist/Hydrogeologist - Has overall responsibility for obtaining water level measurements and developing groundwater contour maps. The site geologist/hydrogeologist (in concurrence with the Project Manager) shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number of data points needed and which wells shall be used for a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - Must have a basic familiarity with the equipment and procedures involved in obtaining water levels, and must be aware of any project-specific requirements.

## **5.0 PROCEDURES**

Accurate, valid and useful groundwater monitoring requires that four important conditions be met:

- Proper characterization of site hydrogeology.
- Proper design of the groundwater monitoring program, including adequate numbers of wells installed at appropriate locations and depths.
- Satisfactory methods of groundwater sampling and analysis to meet the data quality objectives (DQOs).
- The assurance that specific monitoring well samples are representative of water quality conditions in the monitored interval.

To insure that these conditions are met, adequate descriptions of subsurface geology, well construction methods and well testing results must be available. The following steps will help to insure that the required data are available to permit an evaluation of the utility of existing monitoring wells for collecting additional samples.

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### **5.1      Preliminary Evaluation**

A necessary first step in evaluating existing monitoring well data is the study and review of the original work plan for monitoring well installation (if available). This helps to familiarize the site geologist/hydrogeologist with site-specific conditions, and will promote an understanding of the original purpose of the monitoring wells.

The next step of the evaluation should involve a review of all available information concerning borehole drilling and well construction. This will allow interpretation of groundwater flow conditions and area geology, and will help to establish consistency between hydraulic properties of the well and physical features of the well or formation. The physical features which should be identified and detailed, if available, include:

- The well identification number, permit number and location by referenced coordinates, the distance from prominent site features, or the location of the well on a map.
- The installation dates, drilling methods, well development methods, and contractors.
- The depth to bedrock -- where rock cores were not taken, auger refusal, drive casing refusal or penetration test results (blow counts for split-barrel sampling) may be used to estimate bedrock interface.
- The soil profile and stratigraphy.
- The borehole depth and diameter.
- The elevation of the top of the protective casing, the top of the well riser, and the ground surface.
- The total depth of the well.
- The type of well materials, screen type, slot size, and length, and the elevation/depths of the screen, interval, and/or monitored interval.
- The elevation/depths of the tops and bottom of the filter pack and well seals and the type and size.

### **5.2      Field Inspection**

During the onsite inspection of existing monitoring wells, features to be noted include:

- The condition of the protective casing, cap and lock.
- The condition of the cement seal surrounding the protective casing.
- The presence of depressions or standing water around the casing.
- The presence of any electrical cable and its connections.

If the protective casing, cap and lock have been damaged or the cement collar appears deteriorated, or if there are any depressions around the well casing capable of holding water, surface water may have

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infiltrated into the well. This may invalidate previous sampling results since the time when leakage started is unknown.

The routine physical inspection must be followed by a more detailed investigation to identify other potential routes of contamination or sampling equipment malfunction. Any of these occurrences may invalidate previously-collected water quality data. If the monitoring well is to be used in the future, considerations shown in the steps described above should be rectified to rehabilitate the well. After disconnecting any wires, cables or electrical sources, remove the lock and open the cap. Check for the presence of organic vapors with a photoionization detector (PID) or flame-ionization detector (FID) and combustible gas meter to determine the appropriate worker safety level. The following information should be noted:

- Cap function.
- Physical characteristics and composition of the inner casing or riser, including inner diameter and annular space.
- Presence of grout between the riser and outer protective casing and the existence of drain holes in the protective casing.
- Presence of a riser cap, method of attachment to casing, and venting of the riser.
- Presence of dedicated sampling equipment; if possible, remove such equipment and inspect size, materials of construction and condition.

The final step of the field inspection is to confirm previous hydraulic or physical property data and to obtain data not previously available. This includes the determination of static water levels, total well depth and well obstruction. This may be accomplished using a weighted tape measure which can also be used to check for sediment (the weight will advance slowly if sediment is present, and the presence of sediment on the weight upon removal should be noted). If sediment is present, the well be should be redeveloped before sampling.

Lastly, as a final step, the location, condition and expected water quality of the wells should be reviewed in light of their usefulness for the intended purpose of the investigation.

### **5.3      Water Level (Hydraulic Head) Measurements**

#### **5.3.1      General**

Groundwater level measurements can be made in monitoring wells, private or public water wells, piezometers, open boreholes, or test pits (after stabilization). Groundwater measurements should generally not be made in boreholes with drilling rods or auger flights present. If groundwater sampling activities are to occur, groundwater level measurements shall take place prior to well evacuation or sampling.

All groundwater level measurements shall be made to the nearest 0.01 foot, and recorded in the site geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A), along with the date and time of the reading. The total depth of the well shall be measured and recorded, if not already known. Weather changes that occur over the period of time during which water levels are being taken, such as precipitation and barometric pressure changes, should be noted.

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In measuring groundwater levels, there shall be a clearly-established reference point of known elevation, which is normally identified by a mark on the upper edge of the inner well casing. The reference point shall be noted in the field notebook. To be useful, the reference point should be tied in with an established USGS benchmark or other properly surveyed elevation datum. An arbitrary datum could be used for an isolated group of wells, if necessary.

Cascading water within a borehole or steel well casings can cause false readings with some types of sounding devices (chalked line, electrical). Oil layers may also cause problems in determining the true water level in a well. Special devices (interface probes) are available for measuring the thickness of oil layers and true depth to groundwater, if required.

Water level readings shall be taken regularly, as required by the site geologist/hydrogeologist. Monitoring wells or open-cased boreholes that are subject to tidal fluctuations should be read in conjunction with a tidal chart (or preferably in conjunction with readings of a tide staff or tide level recorder installed in the adjacent water body); the frequency of such readings shall be established by the site hydrogeologist. All water level measurements at a site used to develop a groundwater contour map shall be made in the shortest practical time to minimize affects due weather changes, and at least during the same day.

### **5.3.2 Water Level Measuring Techniques**

There are several methods for determining standing or changing water levels in boreholes and monitoring wells. Certain methods have particular advantages and disadvantages depending upon well conditions. A general description of these methods is presented, along with a listing of various advantages and disadvantages of each technique. An effective technique shall be selected for the particular site conditions by the site geologist/hydrogeologist.

In most instances, preparation of accurate potentiometric surface maps require that static water level measurements be obtained to a precision of 0.01 feet. To obtain such measurements in individual accessible wells, chalked tape or electrical water level indicator methods have been found best, and thus are the most often utilized. Other, less precise methods, such as the popper or bell sound, or bailer line methods, may be appropriate for developing preliminary estimates of hydraulic conditions. When a large number of (or continuous) readings are required, time-consuming individual readings are not usually feasible. In such cases, it is best to use the float recorder or pressure transducer methods. When conditions in the well limit readings (i.e., turbulence in the water surface or limited access through small diameter tubing), less precise, but appropriate methods such as the air line or capillary tubing methods can be used (see subsequent SOP section for discussion of these devices).

### **5.3.3 Methods**

Water levels can be measured by several different techniques, but the same steps shall be followed in each case. The proper sequence is as follows:

1. Check operation of recording equipment above ground. Prior to opening the well, don personal protective equipment, as required.
2. Record all information specified below in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A):
  - Well number.

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- Water level (to the nearest 0.01 foot; 0.3 cm). Water levels shall be taken from the surveyed reference mark on the top edge of the inner well casing.
- Time and day of the measurement.

Water level measuring devices with permanently marked intervals shall be used when possible. If water level measuring devices marked by metal or plastic bands clamped at intervals along the measuring line are used, the spacing and accuracy of these bands shall be checked frequently as they may loosen and slide up or down the line, resulting in inaccurate reference points.

#### **5.3.4 Water Level Measuring Devices**

##### **Chalked Steel Tape**

The water level is measured by chalking a weighted steel tape and lowering it a known distance (to any convenient whole foot mark) into the well or borehole. The water level is determined by subtracting the wetted chalked mark from the total length lowered into the hole.

The tape shall be withdrawn quickly from the well because water has a tendency to rise up the chalk due to capillary action. A water finding paste may be used in place of chalk. The paste is spread on the tape the same way as the chalk, and turns red upon contacting water.

Disadvantages to this method include the following: depths are limited by the inconvenience of using heavier weights to properly tension longer tape lengths; ineffective if borehole/well wall is wet or inflow is occurring above the static water level; chalking the tape is time-consuming; difficult to use during periods of precipitation.

##### **Electric Water Level Indicators**

These devices consist of a spool of small-diameter cable and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated monitoring well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, steel well casing, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe shall be lowered slowly into the well. The electric tape is marked at the measuring point where contact with the water surface was indicated. The distance from the mark to the nearest tape band is measured using an engineer's folding ruler or steel tape, and added to the band reading to obtain the depth to water. If the band is not a permanent marking band, spacing shall be checked periodically as described in Section 5.3.6.

##### **Popper or Bell Sounder**

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "plopping" or "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight strikes the water. This method is not sufficiently accurate to obtain water levels to 0.01 feet, and thus is more appropriate for obtaining only approximate water levels quickly.

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### **Float Recorder**

A float or an electromechanically actuated water-seeking probe may be used to detect vertical changes of the water surface in the hole. A paper-covered recording chart drum is rotated by the up and down motion of the float via a pulley and reduction gear mechanism, while a clock drive moves a recording pen horizontally across the chart. To ensure continuous records, the recorder shall be inspected, maintained, and adjusted periodically. This type of device is useful for continuously measuring periodic water level fluctuations, such as tidal fluctuations or influences of pumping wells.

### **Air Line**

An air line is especially useful in pumped wells where water turbulence may preclude the use of other devices. A small-diameter weighted tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air (from a compressor, bottled air, or air pump) is used to purge the water from the tube, until air begins to escape the lower end of the tube, and is seen (or heard) to be bubbling up through the water in the well. The pressure needed to purge the water from the air line multiplied by 2.307 (feet of water for 1 psi) equals the length in feet of submerged air line. The depth to water below the center of the pressure gauge can be calculated by subtracting the length of air line below the water surface from the total length of the air line.

The disadvantages to this method include the need for an air supply and lower level of accuracy (unless a very accurate air pressure gauge is used, this method cannot be used to obtain water level readings to the nearest 0.01 ft).

### **Capillary Tubing**

In small diameter piezometer tubing, water levels are determined by using a capillary tube. Colored or clear water is placed in a small "U"-shaped loop in one end of the tube (the rest of the tube contains air). The other end of the capillary tube is lowered down the piezometer tubing until the water in the loop moves, indicating that the water level has been reached. The point is then measured from the bottom of the capillary tube or recorded if the capillary tube is calibrated. This is the best method for very small diameter tubing monitoring systems such as Barcad and other multilevel systems. Unless the capillary tube is calibrated, two people may be required to measure the length of capillary tubing used to reach the groundwater. Since the piezometer tubing and capillary tubing usually are somewhat coiled when installed, it is difficult to accurately measure absolute water level elevations using this method. However, the method is useful in accurately measuring differences or changes in water levels (i.e., during pumping tests).

### **Pressure Transducer**

Pressure transducers can be lowered into a well or borehole to measure the pressure of water and therefore the water elevation above the transducer. The transducer is wired into a recorder at the surface to record changes in water level with time. The recorder digitizes the information and can provide a printout or transfer the information to a computer for evaluation (using a well drawdown/recovery model). The pressure transducer should be initially calibrated with another water level measurement technique to ensure accuracy. This technique is very useful for hydraulic conductivity testing in highly permeable material where repeated, accurate water level measurements are required in a very short period of time. A sensitive transducer element is required to measure water levels to 0.01 foot accuracy.

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## **Borehole Geophysics**

Approximate water levels can be determined during geophysical logging of the borehole (although this is not the primary purpose for geophysical logging and such logging is not cost effective if used only for this purpose). Several logging techniques will indicate water level. Commonly-used logs which will indicate saturated/unsaturated conditions include the spontaneous potential (SP) log and the neutron log.

### **5.3.5 Data Recording**

Water level measurements, time, data, and weather conditions shall be recorded in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet. All water level measurements shall be measured from a known reference point. The reference point is generally a marked point on the upper edge of the inner well casing that has been surveyed for an elevation. The exact reference point shall be marked with permanent ink on the casing since the top of the casing may not be entirely level. It is important to note changes in weather conditions because changes in the barometric pressure may affect the water level within the well.

### **5.3.6 Specific Quality Control Procedures for Water Level Measuring Devices**

All groundwater level measurement devices must be cleaned before and after each use to prevent cross contamination of wells. Manufacturer's instructions for cleaning the device shall be strictly followed. Some devices used to measure groundwater levels may need to be calibrated. These devices shall be calibrated to 0.01 foot accuracy and any adjustments/corrections shall be recorded in the field logbook/notebook. After the corrections/adjustments are made to the measuring device and entered in the field logbook/notebook, the corrected readings shall be entered onto the Groundwater Level Measuring Sheet (Attachment A). Elevations will be entered on the sheet when they become available.

## **5.4 Health and Safety Considerations**

Groundwater contaminated by volatile organic compounds may release toxic vapors into the air space inside the well pipe. The release of this air when the well is initially opened is a health/safety hazard which must be considered. Initial monitoring of the well headspace and breathing zone concentrations using a PID (e.g., HNu) or FID (e.g., OVA) and combustible gas meters shall be performed to determine required levels of protection.

## **6.0 RECORDS**

A record of all field procedures, tests and observations must be recorded in the site logbook or designated field notebook. Entries in the log/notebook should include the individuals participating in the field effort, and the date and time. The use of annotated sketches may help to supplement the evaluation.







BROWN & ROOT ENVIRONMENTAL

# STANDARD OPERATING PROCEDURES

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Subject  
SOIL AND ROCK DRILLING METHODS

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## 1.0 PURPOSE

The purpose of this procedure is to describe the methods and equipment necessary to perform soil and rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

## 2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits, and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

The sampling methods described within this procedure are applicable to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design and related civil engineering purposes.

## 3.0 GLOSSARY

Rock Coring - A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring - As an alternative to conventional coring, this technique is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique, the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

## 4.0 RESPONSIBILITIES

Project Manager - In consultation with the project geologist, the Project Manager is responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. The Project Manager also determines the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see SOP SA-6.2). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan and/or Sampling and Analysis Plan.

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Drilling Subcontractor - Operates under the supervision of the FOL. Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager).

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

## **5.0 PROCEDURES**

### **5.1 General**

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see SOP SA-6.2). Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

### **5.2 Drilling Methods**

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, the waste conditions at the site, and reviewing the purpose of drilling and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

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### **5.2.1 Continuous-Flight Hollow-Stem Auger Drilling**

This method of drilling consists of rotating augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole. However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations requires the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.
- No drilling fluids are required.
- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.
- The inside diameter of hollow stem augers used for well installation should be at least 4 inches greater than the well casing. Use of such large-diameter hollow-stem augers is more expensive than the use of small-diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.
- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.
- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet.
- Hollow-stem auger drilling is the preferred method of drilling. Most alternative methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods, great care must be taken to ensure that the method does not interfere with the collection of a representative sample (which is the objective of the borehole construction. With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:
  - Cable tool
  - Casing drive (air)
  - Air rotary
  - Mud rotary
  - Rotasonic
  - Drive and wash
  - Jetting

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However, the use of any method will also depend on efficiency and cost-effectiveness. In many cases, mud rotary is the only feasible alternative to hollow-stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The guidelines established in SOP SA-1.3 shall also be followed. The hollow-stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, when drilling below the water table, specially designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This drilling configuration method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see SOP GH-2.1 for well development procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

At the option of the Field Operations Leader (in communication with the Project Manager), when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations, it may be prudent to also grout borings which penetrate only the water table aquifer, since loose soil backfill in the boring may still provide a preferred pathway for surface liquids to reach the water table.

#### **5.2.2 Continuous-Flight Solid-Stem Auger Drilling**

This drilling method is similar to hollow-stem augering. Practical application of this method is severely restricted compared to use of hollow-stem augers. Split-barrel (split-spoon) sampling cannot be performed without pulling the augers out, which may allow the hole to collapse. The continuous-flight solid-stem auger drilling method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid-stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to

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remain open after the augers are withdrawn. Alternatively, this technique can be used to find depth to bedrock in an area when no other information is required from drilling.

### **5.2.3 Rotary Drilling**

Direct rotary drilling includes air-rotary and fluid-rotary drilling. For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and rpm range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air-rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large, to allow room for proper well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.
- In-situ samples cannot be taken, unless the hole is cased.
- Casing must generally be used in unconsolidated materials.
- Air-rotary drill rigs are large and heavy.

A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air-rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air-rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

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Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow-stem auger method if split-barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on subsequent water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This requires either constant replenishment of the drilling fluid, or the use of casing through this formation.
- Drill rigs are large and heavy, and must be supported with supplied water.
- Groundwater samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

Soil samples shall be taken as specified by project plan documents, or more frequently, if requested by the project geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the project geologist.



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#### **5.2.4 Rotosonic Drilling**

The Rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construction of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.
- Continuous sampling, with larger sample volume as compared to split-spoon sampling.
- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.
- Reduction of IDW by an average of 70 to 80 percent.
- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for Rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.
- Rotosonic drill rigs are large and need ample room to drill, however, Rotosonic units can be placed on the ground or placed on an ATV.
- There are a limited number of Rotosonic drilling contractors at the present time.

#### **5.2.5 Reverse Circulation Rotary Drilling**

The common reverse-circulation rig is a water or mud-rotary rig with a large-diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud-rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water quality sampling wells because of the use of drilling muds and the large-diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

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Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air-rotary rig.

Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

#### **5.2.6 Drill-through Casing Driver**

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig (or an air-hammer) and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage); a continuous record is kept of the blows per foot in driving the casing (see SOP GH-1.4). The casing is normally advanced by a 300-pound hammer falling freely through a height of 30 inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations within which wash water is used and in which the casing is driven must be clearly recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least 4 inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split-barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore, multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).

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- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

### **5.2.7 Cable Tool Drilling**

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped, chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water needs to be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.
- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, cable or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).
- When casing is used, the casing seals formation water out of the hole, preventing down hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.
- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.
- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.

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- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required (e.g., such use of a hollow-stem auger).
- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

#### **5.2.8 Jet Drilling (Washing)**

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2- to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch-diameter casing in shallow, unconsolidated sand formations, but this method has also been used to install 3- to 4-inch-diameter casings to a depth of 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.
- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.
- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.
- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.
- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.
- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).
- Large quantities of water are often needed.

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### **5.2.9 Drilling with a Hand Auger**

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the project plan documents. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

### **5.2.10 Rock Drilling and Coring**

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation of this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the project plans. The most common core barrel diameters are listed in Attachment A.

Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole causing unsatisfactory coring, the hole should be reamed and a flush-joint casing installed to a point below the broken formation. The size of the flush-joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

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Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

#### **5.2.11 Drilling & Support Vehicles**

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight, size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand carried to the borehole site. Drilling/sampling methods used with such equipment include:
  - Hand augers and lightweight motorized augers.
  - Retractable plug samplers--driven by hand (hammer).

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- Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small-diameter cased borings. This rig is sometimes called a "monkey on a stick."
- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.
- Small truck-mounted drilling equipment using a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs, the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.
- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.
- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.
- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles include:
  - Barrel-float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.
  - Barge-mounted drill rigs.
  - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.
  - Drill ships - for deep ocean drilling.

In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

#### **5.2.12 Equipment Sizes**

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

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For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8-inch or 7-7/8-inch bits will nominally drill 6-inch and 8-inch holes, respectively).

For obtaining split-barrel samples of a formation, samplers are commonly manufactured in sizes ranging from 2 inches to 3-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used and driven by a 140-pound ( $\pm$  2-pound) hammer dropping 30 inches ( $\pm$  1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow-stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the project plan documents.

#### **5.2.13 Estimated Drilling Progress**

To estimate the anticipated rates of drilling progress for a site, the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30 feet to 50 feet) boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud-Rotary Drilling	100' (cuttings samples)
Rotosonic Drilling	100'-160' (continuous core)
Reverse-Circulation Rotary	100' (cuttings samples)
Skid-Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'



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### 5.3 Prevention of Cross-Contamination

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe (a method similar to the rock coring method described in Section 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 of this guideline) and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing (usually of 8-inch diameter) is installed followed by installation of the well casing (6-inch-diameter is common for 2-inch wells). This well casing is driven into the confining layer to ensure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end, is installed to the surface.

Clean sand is placed in the annulus around and to a point of about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

### 5.4 Cleanout of Casing Prior to Sampling

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward-directed jet which will disturb the underlying soil. When clean out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split-barrel (split-spoon) sampler with the ball check valve removed as the clean-out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split-spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner, there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the clean out auger, a split-barrel sample can be taken to remove it; bailers and

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sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions as to the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.
- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.
- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string, then measuring the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches of cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

## **5.5 Materials of Construction**

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in SOP GH-2.1. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long-term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods and procedures for their use must be provided by the site geologist and approved by the Project Manager. The specific slurry composition and the concentration of suspected contaminants for each site must be known.

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For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field by the judgment of the site geologist and noted in the site logbook, and only after approval by the Project Manager, a vegetable oil or silicone-based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

## **5.6      Subsurface Soil Samples**

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

The CME continuous sample tube system provides a method of sampling soil continuously during hollow-stem augering. The 5-foot sample barrel fits within the lead auger of a hollow-auger column. The sampling system can be used with a wide range of I.D. hollow-stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailings, etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required. Rotasonic drilling methods also provide a continuous soil sample.

## **5.7      Rock Sampling (Coring) (ASTM D2113-83)**

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and yields better quality data than air rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average

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output in a 10-hour day ranges from 40 to over 200 feet. Down hole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Figure 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross-contamination of aquifers.

Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

#### **5.7.1 Diamond Core Drilling**

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split-barrel sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used:

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross-contamination of aquifers in the unconsolidated materials is unlikely, leveling may be omitted.
- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.
- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split-barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling); sample soils per SOP SA-1.3. Resume diamond core drilling when refusal materials are again encountered.
- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as conditions warrant.

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FIGURE 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line __ __/ Wire line	1 7/8	1	1.875	1.000
BX Wire line __ __/ Wire line	2 3/8	1 7/16	2.345	1.437
NX Wire line __ __/ Wire line	3	1 15/16	2.965	1.937

\* All dimensions are in inches; to convert to millimeters, multiply by 254.  
 \_\_|\_\_/  
 Wire line dimensions and designations may vary according to manufacturer.

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**FIGURE 1**  
**STANDARD SIZES OF CORE BARRELS AND CASING**  
**PAGE TWO**

Size Designations		Casing O.D., Inches	Casing Coupling		Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings		O.D., Inches	I.D., Inches				Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush Joint	No Coupling	1.485	1.160	1.094	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	---	5.500			5.650	---	---	---	---
SW	---	6.625			6.790	---	---	---	---
UW	---	7.625			7.800	---	---	---	---
ZW	---	8.625			8.810	---	---	---	---
---	AX ___ ___\	---	---	---	---	1.875	1.750	1.000	---
---	BX ___ ___\	---	---	---	---	2.345	2.250	1.437	---
---	NX ___ ___\	---	---	---	---	2.965	2.813	1.937	---

\* All dimensions are in inches; to convert to millimeters, multiply by 254.  
\_\_\_|\_\_\_/ Wire line dimensions and designations may vary according to manufacturer

**NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES.**  
**(DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889**

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- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

#### **5.7.2 Rock Sample Preparation and Documentation**

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in SOP GH-1.4. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as designating the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Project Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows.

The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box. The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box. The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name.
- Project number.
- Boring number.
- Run numbers.
- Footage (depths).
- Recovery.
- RQD (%).
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number.

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Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

## 6.0 REFERENCES

Acker Drill Co., 1958. Basic Procedures of Soil Sampling. Acker Drill Co., Scranton, Pennsylvania.

American Institute of Steel Construction, 1978. Manual of Steel Construction, 7th Edition. American Institute of Steel Construction, New York, New York.

American Society for Testing and Materials, 1987. ASTM Standards D1587-83, D1586-84, and D1452-80. ASTM Annual Book of Standards, ASTM, Philadelphia, Pennsylvania, Vol. 4.08.

American Society for Testing and Materials, 1989. Standard Practice for Diamond Core Drilling for Site Investigation. ASTM Method D2113-83 (reapproved 1987), Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

Barcelona, M. J., J. P. Gibb and R. A. Miller, 1983. A Guide to the Selection of Material for Monitoring Well Construction and Ground Water Sampling. ISWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois.

BOART Longyear Co., Sonic Drilling. Environmental Drilling Division, Andova, Minnesota.

Central Mine Equipment Company, Drilling Equipment, St. Louis, Missouri.

Dept. of the Navy, Naval Facilities Engineering Command, 1982. Soil Mechanics Design Manual 7.1.

Driscoll, Fletcher G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division, St. Paul, Minnesota.

Procedure GH-1.5 - Borehole and Sample Logging.

Scaif, M. R., J. F. McNabb, W. J. Dunlap, R. L. Crosby and J. Fryberger, 1981. Manual of Ground-Water Sampling Procedures. NWWA/EPA Series. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Ada, Oklahoma.

U.S. Department of the Interior, 1974, Earth Manual, A Water Resources Technical Publication, 810 pages.

U.S. EPA, 1980. Procedure Manual for Ground Water Monitoring at Solid Waste Disposal Facilities. SW-611. Office of Solid Waste, U.S. EPA, Cincinnati, Ohio.

W. L. Acker III, 1974. Basic Procedures for Soil Sampling and Core Drilling. Acker Drill Co., Inc., Scranton, Pennsylvania.



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**ATTACHMENT A**  
**DRILLING EQUIPMENT SIZES**

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Hollow-stem augers (Ref. 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	---
	7 1/4	6 1/4	3 1/4	---
	13 1/4	12	6	---
Thin Wall Tube Samplers (Ref. 7)	---	2	1 7/8	---
	---	2 1/2	2 3/8	---
	---	3	2 7/8	---
	---	3 1/2	3 3/8	---
	---	4 1/2	4 3/8	---
	---	5	4 3/4	---
Drill Rods (Ref. 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (Inches)
Driven External Coupled Extra Strong Steel* Casing (Ref. 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

\* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

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**ATTACHMENT A  
DRILLING EQUIPMENT SIZES  
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Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Flush Coupled Casing (Ref. 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref. 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref. 7)	EWM	1 1/2	7/8**	
	AWM	1 7/8	1 1/8**	
	BWM	2 3/8	1 5/8**	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16**	
	BQ (wireline)	2 23/64	1 7/16**	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

\*\* Because of the fragile nature of the core and the difficulty to identify rock details, use of small-diameter core (1 3/8") is not recommended.



**BROWN & ROOT ENVIRONMENTAL**

# STANDARD OPERATING PROCEDURES

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Prepared  
Earth Sciences Department

Subject

BOREHOLE AND SAMPLE LOGGING

Approved  
D. Senovich

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## **1.0 PURPOSE**

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

## **2.0 SCOPE**

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

## **3.0 GLOSSARY**

None.

## **4.0 RESPONSIBILITIES**

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used on site, the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

## **5.0 PROCEDURES**

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

### **5.1 Materials Needed**

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute hydrochloric acid (HCl)
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

### **5.2 Classification of Soils**

All data shall be written directly on the boring log (Figure 1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

#### **5.2.1 USCS Classification**

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (Continued).



FIGURE 1 (CONTINUED)

## SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)											
COARSE-GRAINED SOILS More Than Half of Material is LARGER Than No. 200 Sieve Size					FINE-GRAINED SOILS More Than Half of Material is SMALLER Than No. 200 Sieve Size						
FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 1/4" and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES	FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 1/4" and Basing Fractions on Estimated Weights)				GROUP SYMBOL	TYPICAL NAMES	
					Identification Procedures on Fraction Smaller Than No. 40 Sieve Size						
						DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)			
GRAVELS (50% (+) > 1/4")	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	SILTS AND CLAYS Liquid Limit < 50	None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.	
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel sand mixtures, little or no fines.		Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.		Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.	
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel sand-clay mixtures.	SILTS AND CLAYS Liquid Limit > 50	Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	
SANDS 50% (+) < 1/4")	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.		High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.	
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.		Medium to High	None to Very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.	
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see MCL)	SM	Silty sands, poorly graded sand silt mixtures.	HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			PT	Peat and other organic soils	
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand-clay mixtures.							

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW-GC, well graded gravel sand mixture with clay binder. All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS	
DESIGNATION	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS			
CONSISTENCY	UNC. COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist.
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

## ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENNESS		
Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects	Descriptive Terms	Abbreviation	Spacing
Soft	Easily gouged	Crushes when pressed with hammer	Very Broken	(V. Br.)	0-2"
Medium Soft	Can be gouged	Breaks (one blow); crumbly edges	Broken	(Br.)	2"-1'
Medium Hard	Can be scratched	Breaks (one blow); sharp edges	Blocky	(Bl.)	1'-3"
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges	Massive	(M.)	3'-10'

## LEGEND:

## SOIL SAMPLES - TYPES

- 5.2" Split-Barrel Sample  
 ST-3" O.D. Undisturbed Sample  
 0 Other Samples, Specify in Remarks

## ROCK SAMPLES - TYPES

- X-MX (Conventional) Core (-2-1/8" O.D.)  
 Q-MQ (Wireline) Core (-1-7/8" O.D.)  
 2 Other Core Sizes, Specify in Remarks

## WATER LEVELS

- 12/18 Initial Level w/Date & Depth  
 12.6'

- 12/18

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This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inch $\Phi$ -1/2 inch $\Phi$ )" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

#### 5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

#### 5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split-barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.2. Those designations are:



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Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength), or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in Figure 2.

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**FIGURE 2**  
**CONSISTENCY FOR COHESIVE SOILS**

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented with difficulty by thumbnail

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#### 5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

#### 5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

#### 5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Figure 3.

#### 5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

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**FIGURE 3**

**BEDDING THICKNESS CLASSIFICATION**

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

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### 5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

### ~~5.3 Classification of Rocks~~

Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.
- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.
- Shale - A fissile very fine-grained rock. Fractures along bedding planes.
- Limestone - Rock made up predominantly of calcite ( $\text{CaCO}_3$ ). Effervesces strongly upon the application of dilute hydrochloric acid.
- Coal - Rock consisting mainly of organic remains.
- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

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### **5.3.1 Rock Type**

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Figure 4 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

### **5.3.2 Color**

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock color charts shall not be used unless specified by the Project Manager.

### **5.3.3 Bedding Thickness**

The bedding thickness designations applied to soil classification (see Figure 3) will also be used for rock classification.

### **5.3.4 Hardness**

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

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#### FIGURE 4

#### GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm

After Wentworth, 1922

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### 5.2.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2-inch spacing between fractures
- Broken (BR.) - 2-inch to 1-foot spacing between fractures
- Blocky (BL.) - 1- to 3-foot spacing between fractures
- Massive (M.) - 3 to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD  
(After Deere, 1964)

$$RQD \% = r/l \times 100$$

$r$  = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

$l$  = Total length of the coring run.

### 5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.
- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.
- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.
- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

### 5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified)



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- ~~Description of any lined cavities or vugs.~~
- Cementation (calcareous, siliceous, hematitic).
  - Description of any joints or open fractures.
  - Observation of the presence of fossils.
  - Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

### 5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."
- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."
- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."
- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.
- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.
- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.
- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.
- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse-grained dark igneous rock.

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~~The following are some basic names that are applied to metamorphic rocks.~~

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine- to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

#### 5.4 Abbreviations

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine-grained
Tr - Trace		

#### 5.5 Boring Logs and Documentation

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use.

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**FIGURE 5  
COMPLETED BORING LOG (EXAMPLE)**



**BORING LOG**

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PROJECT NAME:	NSB- SITE	BORING NUMBER:	SB/MW 1
PROJECT NUMBER:	9594	DATE:	3/8/96
DRILLING COMPANY:	SOILTEST CO.	GEOLOGIST:	SJ CONTI
DRILLING RIG:	CME-55	DRILLER:	R. ROCK

Sample No. and Type or RQD	Depth (FL) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			U S C S *	Remarks	PIDFID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole BZ	Driller BZ
S-1 C 0800	0.0 2.0	7 9	1.5 2.0		M DENSE	BRN TO BLK	SILTY SAND - SOME ROCK FR. - TR BRICKS (FILL)	SM	MOIST SL. ORG. ODOR FILL TO 4'±	5	0	0	0
	4.0			4.0									
S-2 C 0810	5.0 6.0	5 8	2.0 2.0		M DENSE	BRN	SILTY SAND - TR FINE GRAVEL	SM	MOIST - W ODOR NAT. MATL. TOOK SAMPLE SB01-0406 FOR ANALYSIS	10	0	-	-
	8.0			7'± 8.0									
S-3 C 0820	9.0 10.0	6 17	1.9 2.0		DENSE	TAN BRN	FINE TO COARSE SAND TR.F. GRAVEL	SW	WET HIT WATER = 7'±	0	0	0	0
	12.0			12.0									
S-4 C 0830	13.0 14.0	7 8	1.6 2.0		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET	0	.5	-	-
	15.0			15.0					AUGER REF 15'				
				16.0	M HARD	BRN	SILTSTONE	NBR	WEATHERED				
				17.0					LO & JNTS @ 15.5 WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
				18.0					LOSING SOME				
	20.0			19.0	HARD	GRAY	SANDSTONE - SOME SILTSTONE	BR	DRILL H2O @ 17'± SET TEMP 6" CAS TO 15.5				
				20.0					SET 2"Ø PVC SCREEN 16-25	0	0	0	0
				21.0					SAND 14-25				
	25.0			25.0					PELLETS 12-14				

\* When rock coring, enter rock brokenness.

\*\* Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

Remarks: CME-55 RIG, 4 1/4" ID HSA - 9" OD ±  
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP  
NIX CORE IN BEDROCK RUN (1) = 25 min, RUN (2) = 15 min

Converted to Well: Yes ☒ No ☐ Well I.D. #: MW-1

• 1-20Z Drilling Area  
1-80Z Background (ppm): 0

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### 5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology at 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.
- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split-spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.
- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.
- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart on back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.
- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:
  - Trace: 0 - 10 percent
  - Some: 11 - 30 percent
  - And/Or: 31 - 50 percent
- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.
- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.
- The following information shall be entered under the "Remarks" column and shall include, but is not limited by, the following:
  - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

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- Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
- Particle shape - flat, elongated, or flat and elongated.
- Maximum particle size or dimension.
- Water level observations.
- Reaction with HCl - none, weak, or strong.

• Additional comments:

- Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
- Indicate odor and Photoionization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.
- Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.
- At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).
- Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

~~5.5.2 Rock Classification~~

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

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- Enter color as determined while the core sample is wet, if the sample is cored by air, the core shall be scraped clean prior to describing color.
- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.
- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.
- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
  - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
  - Indicate calcareous zones, description of any cavities or vugs.
  - Indicate any loss or gain of drill water.
  - Indicate drop of drill tools or change in color of drill water.
- Remarks at the bottom of Boring Log shall include:
  - Type and size of core obtained.
  - Depth casing was set.
  - Type of rig used.
- As a final check the boring log shall include the following:
  - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
  - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

### 5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock"

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bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.).  
Cuttings shall be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Figure 1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

#### 5.6 Review

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs.
- Checking for conformance to the guideline.
- Checking to see that all information is entered in their respective columns and spaces.

#### 6.0 REFERENCES

Unified Soil Classification System (USCS).

ASTM D2488, 1985.

Earth Manual, U.S. Department of the Interior, 1974.

#### 7.0 RECORDS

Originals of the boring logs shall be retained in the project files.



BROWN & ROOT ENVIRONMENTAL

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1

Applicability  
B&R Environmental, NE

Prepared  
Earth Sciences Department

Subject

GROUNDWATER MONITORING POINT INSTALLATION

Approved  
D. Senovich

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## 1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

## 2.0 SCOPE

This procedure is applicable to the construction of permanent monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

## 3.0 GLOSSARY

Monitoring Well - A well which is properly screened (if screening is necessary, e.g., open borehole), cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

## 4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Rig Geologist - The rig geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

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## 5.0 PROCEDURES

### 5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well:

- Health and safety equipment as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installations tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

### 5.2 Well Design

The objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials to be used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow and potential well locations can be determined through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

#### 5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the levels at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The

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well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (1 to 2 feet) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. However, drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole monitoring wells are required. In the smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced, however, the type of sampling devices that can be used are limited. In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples). The volume of water in the monitoring well available for sampling is dependent on the well diameter as follows:

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Casing Inside Diameter (Inch)	Standing Water Depth to Obtain 1 Gallon Water (Feet)	Total Depth of Standing Water for 4 Gallons (Feet)
2	6.13	25
4	1.53	6
6	0.68	3

However, if a specific well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells; however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

#### 5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength" and Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed. Properties of these two materials are compared in Attachment B. Stainless steel is preferred where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, and ease of manipulation; however, there are also some questions about organic chemical sorption and leaching that are currently being researched (see Barcelona et al., 1983). Concern about the use of PVC can be minimized if PVC wells are used strictly for geohydrologic measurements and not for chemical sampling. The crushing strength of PVC may limit the depth of installation, but Schedule 80 materials normally used for wells greater than 50 feet deep may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe, may corrode and release metal ions or chemically react with organic constituents, but this is considered by some to be less of a problem than the problem associated with PVC material. Galvanized steel is not

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recommended where samples may be collected for metal analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints at slightly more costs. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary and the screened interval is artificially packed with a fine sand. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The rig geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. (For example, as a standard procedure, a Morie No. 1 or Ottawa sand may be used with a 0.010-inch slot screen, however, with a 0.020-inch slot screen, the filter pack material must be the material retained on a No. 20 to No. 30 U.S. standard sieve.)

### **5.2.3 Annular Materials**

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a fine-to medium-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed), and the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets extending to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging, and to provide a better seal. However, in shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of two assemblages of material, (e.g., cement-bentonite). A cement-bentonite grout normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus

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3 to 5 pounds of granular or flake-type bentonite, and 6 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets or equivalent. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

#### **5.2.4 Protective Casing**

When the well is completed and grouted to the surface, a protective steel casing is often placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter protective sleeve is set into the wet cement around the well with the top set level with the pavement. A manhole-type lid placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

### **5.3 Monitoring Well Installation**

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

#### **5.3.1 Monitoring Wells in Unconsolidated Sediments**

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater

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than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack.

The cement-bentonite grout is then mixed and either poured or tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

In stable formations where borehole collapse does not occur, the well can be installed as discussed above, and the use of a temporary casing is not needed. However, centralizers may have to be installed, one above and one below the screen, to assure enough annular space for sand pack placement.

### ~~5.3.2 Confining Layer Monitoring Wells~~

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between the unconfined and confined aquifer. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 3 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting the outer casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells (with the exception of not using a temporary casing during installation). Sufficient time (determined by the rig geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

### 5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 feet into the bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued through the bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. However, if a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be installed temporary until final well installation is completed.

### 5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be driven to depths exceeding 20 feet.

### 5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only one or two small-diameter tubes extending to the surface.

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Manufacturers of these types of samplers claim that four samplers can be installed in a 3-inch-diameter borehole. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. These samplers also perform well when the water table is within 25 feet of the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each manufacturer offers various construction materials.

Two additional types of multilevel sampling systems have been developed. Both employ individual screened openings through a small-diameter casing. One of these systems (marketed by Westbay Instruments Ltd. of Vancouver, British Columbia, Canada) uses a screened port and a sampling probe to obtain samples and head measurements or perform permeability tests. This system allows sampling ports at intervals as close as 5 feet, if desired, in boreholes from 3 to 4.8 inches in diameter.

The second system, developed at the University of Waterloo at Waterloo, Ontario, Canada, requires field assembly of the individual sampling ports and tubes that actuate a simple piston pump and force the samples to the surface. Where the depth to ground water is less than 25 feet, the piston pumps are not required. The assembly is made of easily obtained materials; however, the cost of labor to assemble these monitoring systems may not be cost-effective.

#### ~~5.4 Well Development Methods~~

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) that sufficient development is reached. The selection of the well development method shall be made by the rig geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

##### ~~5.4.1 Overpumping and Backwashing~~

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

##### ~~5.4.2 Surging with a Surge Plunger~~

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is used to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and



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~~plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.~~

### 5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

### 5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed from the screen during this process can then be bailed or pumped from the well.

## 6.0 REFERENCES

Scalf, M. R., J. F. McNabb, W. J. Dunlap, R. L. Cosby, and J. Fryberger, 1981. Manual of Groundwater Sampling Procedures. R. S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Ada, Oklahoma.

Barcelona, M. J., P. P. Gibb and R. A. Miller, 1983. A Guide to the selection of Materials for Monitoring Well Construction and Groundwater Sampling. ISWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois.

U.S. EPA, 1980. Procedures Manual for Groundwater Monitoring of Solid Waste Disposal Facilities. Publication SW-611, Office of Solid Waste, U.S. EPA, Washington, D.C.

Driscoll, Fletcher G., 1986. Groundwater and Wells. Johnson Division, St. Paul, Minnesota, 1989.

## 7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed thus ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information

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will need to be recorded depending on whether the well is completed in overburden, in a confined layer, in bedrock with a cased well, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have a general idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

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## ATTACHMENT A

### RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

#### Preliminary Ranking of Rigid Materials:

- |    |                     |   |                  |
|----|---------------------|---|------------------|
| 1  | Teflon®             | 5 | Lo-Carbon Steel  |
| 2  | Stainless Steel 316 | 6 | Galvanized Steel |
| 3. | Stainless Steel 304 | 7 | Carbon Steel     |
| 4  | PVC 1               |   |                  |

\* Trademark of DuPont

### RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially- Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®*	Silicone	Neoprene	Teflon®*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

#### Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

- |    |                        |   |                        |
|----|------------------------|---|------------------------|
| 1  | Teflon®                | 5 | PE Conventional        |
| 2  | Polypropylene (PP)     | 6 | Plexiglas/Lucite (PMM) |
| 3. | PVC Flexible/PE Linear | 7 | Silicone/Neoprene      |
| 4  | Viton®                 |   |                        |

\* Trademark of DuPont

Source: Barcelona et al., 1983

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## ATTACHMENT B

### COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

\* See also Attachment A.



BROWN & ROOT ENVIRONMENTAL

# STANDARD OPERATING PROCEDURES

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Prepared Earth Sciences Department	
Approved D. Senovich	

Subject

GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER  
QUALITY TESTING

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## 1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

## 2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

## 3.0 GLOSSARY

Conductance - The conductance of a conductor 1 centimeter long and 1 square centimeter in cross-sectional area. For groundwater measurements, a volume of water contained in a 1 cm x 1 cm sample container (the water acts as the conductor). Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only the current flows in the opposite direction due to the external source of applied voltage. Electrolytic cells are used in dissolved oxygen measurement.

Galvanic Cell - A electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit. Galvanic cells are used in dissolved oxygen measurement.

Ohm - Standard unit of electrical resistance (R). Used in specific conductance measurement. A siemen (or umho) is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law,  $E = IR$ , where E is the potential difference, I is the current, and R is the resistance. Used in measurement of specific conductance.

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#### 4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

Project Geologist - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

#### 5.0 PROCEDURES

##### 5.1 General

To be useful and accurate, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of analysis in order to keep any changes in water quality parameters to a minimum.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.
2. For wells that can be purged dry, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is required.
3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:
  - A submersible pump or the intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level drops. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.

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- The intake line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e., floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

## 5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling ground water wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Thermometer, pH paper/meter, camera and film (if appropriate), appropriate keys (for locked wells), engineer's rule, water level indicator, specific conductivity meter, and turbidity meter (as applicable).
- Pumps
  - Shallow-well pumps: Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing) where applicable.
  - Deep-well pumps: Submersible pump and electrical power-generating unit, or air-lift apparatus where applicable.
- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary). Bailers or submersible centrifugal pumps shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.
- Pails - Plastic, graduated.
- Decontamination solutions - Deionized water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvents (e.g., methanol, acetone, hexane), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.



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### 5.3 Calculations of Well Volume

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well by sounding using a clean, decontaminated, weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).

- Calculate one static well volume in gallons  $V = (0.163)(T)(r^2)$

where:  $V$  = Static volume of well in gallons.  
 $T$  = Thickness of water table in the well measured in feet (i.e., linear feet of static water).  
 $r$  = Inside radius of well casing in inches.  
 $0.163$  = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

### 5.4 Evacuation of Static Water (Purging)

#### 5.4.1 General

The amount of purging a well shall receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately the well can be pumped until the parameters such as temperature, electrical conductance, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

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#### 5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A provides guidance on the proper evacuation device to use for given sampling situations. Note that all of these techniques involve equipment which is portable and readily available.

##### Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

##### Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics.

##### Air-Lift Samplers

This group of pump samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Air (or gas)-lift samplers are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation, or loss of volatile organics.

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### Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components can be difficult and time-consuming.

## 5.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO) Concentration
- Oxidation Reduction Potential
- Certain Dissolved Constituents Using Specific Ion Elements
- Turbidity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

### 5.5.1 Measurement of pH

#### 5.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

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Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

#### 5.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or basicity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or basicity determination) and specific pH range hydron paper.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to (in this instance, hydrogen) ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to the ion concentration is generated and measured.

#### 5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone 150 portable pH meter, or combination meter (e.g., HANNA U-10), or combination meter equipped with an in-line sample chamber.
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

#### 5.5.1.4 Measurement Techniques for Field Determination of pH

##### pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.

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- Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- Calibrate on a daily use basis following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.
- Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- Read and record the pH of the solution. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.
- Rinse the electrode(s) with deionized water.
- Store the electrode(s) in an appropriate manner when not in use.

Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

### **pH Paper**

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper and proceed with successively narrower range paper until the sample pH is adequately determined.

### **5.5.2 Measurement of Specific Conductance**

#### **5.5.2.1 General**

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

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It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

#### 5.5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

#### 5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available which may also be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirement of the sampling program.

#### 5.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration. Attachment B provides guidance in this regard.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.

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- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature (if applicable).
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

### 5.5.3 Measurement of Temperature

#### 5.5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

#### 5.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

#### 5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is used, the instrument shall be calibrated according to manufacturer's recommendations.

### 5.5.4 Measurement of Dissolved Oxygen Concentration

#### 5.5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

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The monitoring method discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

#### 5.5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, while leaving the surface of the solution undisturbed.

Dissolved oxygen probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide, which are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

#### 5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

#### 5.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked in the warehouse before going to the field.



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- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment C).
- Record all pertinent information on an equipment calibration sheet.
- Rinse the probe with deionized water.
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells can be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Rinse the probe with deionized water.
- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or if a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

### 5.5.5 Measurement of Oxidation-Reduction Potential

#### 5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

#### 5.5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and is dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

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#### 5.5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

#### 5.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.
- Thoroughly rinse the electrode with deionized water.
- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases and the ORP will decrease if the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.
- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of deionized water from a wash bottle. Place the sample in a clean container and insert the electrodes. Set temperature compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook or sample logsheet, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

#### 5.5.6 Measurement of Turbidity

##### 5.5.6.1 General

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

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It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

#### 5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidimeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

#### 5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Stand alone portable turbidity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

#### 5.5.6.4 Measurements Techniques for Specific Conductance

The steps involved in taking turbidity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the probe in the sample and measure the turbidity. The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.

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- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.
- Rinse the electrode with deionized water.

## 5.6 Sampling

### 5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
- Sample preservation requirements.
- Work schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

### 5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) on the escaping gases at the well head to determine the need for respiratory protection.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwater sampling log sheet (see SOP SA-6.3); then calculate the fluid volume in the well pipe (as previously described in this SOP).
3. Calculate well volume to be removed as stated in Section 5.3.

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4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.
5. Lower the purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (as applicable). Lower the purging device, as required, to maintain submergence.
6. Measure the rate of discharge frequently. A graduated bucket and stopwatch are most commonly used; other techniques include use of pipe trajectory methods, weir boxes or flow meters.
7. Observe the peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. Never collect volatile organics samples using a vacuum pump.
8. Purge a minimum of three to five casing volumes before sampling. In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Purged water shall be collected in a designated container and disposed in an acceptable manner.
9. If sampling using a pump, lower the pump intake to midscreen (or the middle of the open section in uncased wells) and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling.
10. (For pump and packer assembly only). Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. Purge a volume equal to at least twice the screened interval (or unscreened open section volume below the packer) before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
11. In the event that recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record this occurrence in the site logbook.
12. Fill sample containers (preserve and label as described in SOPs SA-6.2 and SA-6.1).
13. Replace the well cap and lock as appropriate. Make sure the well is readily identifiable as the source of the samples.
14. Process sample containers as described in SOPs SA-6.2 and SA-6.1.
15. Decontaminate equipment as described in SOP SA-7.1.

## 5.7 Low Flow Purging and Sampling

### 5.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain

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"representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 2 inches or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 5 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

#### 5.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon). Peristaltic pumps may be used only for inorganic sample collection.
- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing - Teflon, Teflon lined polyethylene, polyethylene, PVC, tygon steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies.
- Interface probe, if needed.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - eH and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (e.g., well purging forms).
- Sample Bottles.

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- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

### 5.7.3 Purging and Sampling Procedure

Use a submersible pump to purge and sample monitoring wells which have a 2.0 inch or greater well casing diameter.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump, safety cable, tubing and electrical lines slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbid free water samples may be difficult if there is three feet or less of standing water in the well.

When starting the pump, slowly increase the pump speed until a discharge occurs. Check water level. Adjust pump speed to maintain little or no water level drawdown. The target drawdown should be less than 0.3 feet and it should stabilize. If the target of less than 0.3 feet cannot be achieved or maintained, the sampling is acceptable if remaining criteria in the procedure are met. Subsequent sampling rounds will probably have intake settings and extraction rates that are comparable to those used in the initial sampling rounds.

Monitor water level and pumping rate every three to five minutes (or as appropriate) during purging. Record pumping rate adjustments and depths to water. Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During initial pump start-up, drawdown may exceed the 0.3 feet target and then recover as pump flow adjustments are made (minimum purge volume calculations should utilize stabilized drawdown values, not the initial drawdown). If the recharge rate of the well is less than minimum capability of the pump do not allow the water level to fall to the intake level (if the static water level is above the screen, avoid lowering the water level into the screen). Shut off the pump if either of the above is about to occur and allow the water level to recover. Repeat the process until field indicator parameters stabilize and the minimum purge volume is removed. The minimum purge volume with negligible drawdown (0.3 feet or less) is two saturated screen length volumes. In situations where the drawdown is greater than 0.3 feet and has stabilized, the minimum purge volume is two times the saturated screen volume plus the stabilized drawdown volume. After the minimum purge volume is attained (and field parameters have stabilized) begin sampling. For low yields wells, commence sampling as soon as the well has recovered sufficiently to collect the appropriate volume for all anticipated samples.

During well purging, monitor field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every three to five minutes (or as appropriate). Purging is complete and sampling may begin when

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all field indicator parameters have stabilized (variations in values are within ten percent of each other, pH +/- 0.2 units, for three consecutive readings taken at three to five minute intervals). If the parameters have stabilized, but turbidity remains above 5 NTU goal, decrease pump flow rate, and continue measurement of parameters every three to five minutes. If pumping rate cannot be decreased any further and stabilized turbidity values remain above 5 NTU goal record this information. Measurements of field parameters should be obtained (as per Section 5.5) and recorded.

VOC samples are preferably collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

## 6.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

Barcelona, M. J., J. P. Gibb and R. A. Miller, 1983. A guide to the Selection of Materials for Monitoring Well Construction and Groundwater Sampling. ISWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois.

Johnson Division, UOP, Inc. 1975. Ground Water and Wells, A Reference Book for the Water Well Industry. Johnson Division, UOP, Inc., Saint Paul, Minnesota.

Nielsen, D. M. and G. L. Yeates, 1985. A Comparison of Sampling Mechanisms Available for Small-Diameter Ground Water Monitoring Wells. Ground Water Monitoring Review 5:83-98.

Scalf, M. R., J. F. McNabb, W. J. Dunlap, R. L. Crosby and J. Fryberger, 1981. Manual of Ground Water Sampling Procedures. R. S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Ada, Oklahoma.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. EPA, 1980. Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities. Office of Solid Waste, United States Environmental Protection Agency, Washington, D.C.

U.S. EPA, 1994. Groundwater Sampling Procedure - Low Flow Purge and Sampling (Draft Final). U.S. Environmental Protection Agency, Region I.



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U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition. Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

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**ATTACHMENT A**  
**PURGING EQUIPMENT SELECTION**

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level < 25 feet		X	X	X	X			
	Water Level > 25 feet				X				
2-Inch	Water level < 25 feet	X	X	X	X	X	X		
	Water Level > 25 feet	X			X		X		
4-Inch	Water level < 25 feet	X	X	X	X	X	X	X	X
	Water Level > 25 feet	X			X		X	X	X
6-Inch	Water level < 25 feet				X	X		X	X
	Water Level > 25 feet				X			X	X
8-Inch	Water level < 25 feet				X	X		X	X
	Water Level > 25 feet				X			X	X

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ATTACHMENT A  
PURGING EQUIPMENT SELECTION  
PAGE 2

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	\$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	< 1.0/NA	(not submersible) Tygon®, silicone Viton®	0-30	670 mL/min with 7015-20 pump head	\$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	< 1.5 or < 2.0/NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	\$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon®	No limit	1,075 mL	\$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	\$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	\$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volume	\$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	\$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-160	0-4,500 mL/min	\$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	\$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	\$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	\$300-400	Requires compressed gas; piezometric level indicator; other materials available.

Subject

GROUNDWATER SAMPLE  
ACQUISITION AND ONSITE WATER  
QUALITY TESTING

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ATTACHMENT A  
PURGING EQUIPMENT SELECTION  
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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	<0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	\$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	\$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/flushing cycle	\$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	\$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	\$20-60	Other sizes, materials, models available; optional bottom-emptying device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/flushing cycle	\$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	\$800-1,000	Compressed gas required; DC control module; custom built.

## Construction Material Abbreviations:

PE Polyethylene  
 PP Polypropylene  
 PVC Polyvinyl chloride  
 SS Stainless steel  
 PC Polycarbonate  
 EPDM Ethylene-propylene diene (synthetic rubber)

## Other Abbreviations:

NA Not applicable  
 AC Alternating current  
 DC Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983.

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# **ATTACHMENT B**

## **SPECIFIC CONDUCTANCE OF 1 MOLAR KCl AT VARIOUS TEMPERATURES<sup>1</sup>**

Temperature (°C)	Specific Conductance (umhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

<sup>1</sup> Data derived from the International Critical  
Tables 1-3-8.

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### ATTACHMENT C

#### VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

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**ATTACHMENT C**  
**VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER**  
**AS A FUNCTION OF TEMPERATURE AND SALINITY**  
**PAGE TWO**

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore, used to correct measured D.O. concentration) using Attachment B.



BROWN & ROOT ENVIRONMENTAL

# STANDARD OPERATING PROCEDURES

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Applicability  
B&R Environmental, NE

Prepared  
Earth Sciences Department

Subject

NON-RADIOLOGICAL SAMPLE HANDLING

Approved  
D. Senovich

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## 1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

## 2.0 SCOPE

This procedure:

- Describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped off site for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with current U.S. Department of Transportation (DOT) regulations.

## 3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173.

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (y261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (y261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

ORM - Other regulated material (see DOT 49 CFR 173.144).

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

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#### Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H<sub>2</sub>SO<sub>4</sub>
- Nitric Acid - HNO<sub>3</sub>
- Sodium Hydroxide - NaOH

#### Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent. Thus, a one-molar solution of HCl, containing 1 gram-atom of H, is "one normal," whereas a one-molar solution of H<sub>2</sub>SO<sub>4</sub>, containing 2 gram-atoms of H, is "two normal."

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

## 4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the common carrier.

## 5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

### 5.1 Sample Containers

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of bottle orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

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Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or a missing Teflon liner (if required for the container), shall be discarded.

## 5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected. Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing (certain biological samples only).

### 5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. In general, aqueous samples of low-concentration organics (or soil samples of low- or medium-concentration organics) are cooled to 4°C. Medium-concentration aqueous samples and high-hazard organics samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO<sub>3</sub>, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not preserved.

The following subsections describe the procedures for preparing and adding chemical preservatives. Attachments A and B indicate the specific analytes which require these preservatives.

### 5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H <sub>2</sub> SO <sub>4</sub> )	1 part concentrated H <sub>2</sub> SO <sub>4</sub> : 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO <sub>3</sub> )	Undiluted concentrated HNO <sub>3</sub>	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

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The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample (assuming that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required). Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.
- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).
- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

Continue with proper base preservation of the sample as described, generally, above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

The sample pH is then raised to 9 using the NaOH preservative.

- To test if sodium thiosulfate must be added to remove residual chlorine from a sample, test the sample for residual chlorine using a field test kit especially made for this purpose.

If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

Continue with proper acidification of the sample as described, generally, above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory before sampling begins.

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### 5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated silicon tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).
- To perform filtration, thread the silicon tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration.
- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

### 5.4 Sample Packaging and Shipping

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples (if there is any doubt, a sample shall be considered hazardous and shipped accordingly.)
- Protect the health and safety of transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental and hazardous material samples are outlined in the remainder of this section.

#### 5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place sample container, properly identified and with lid securely fastened in a plastic bag (e.g. Ziploc baggie), and seal the bag.
- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic (e.g. "garbage" bag).
- Pack with enough noncombustible, absorbent, cushioning materials such as vermiculite (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

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- If cooling is required (see Attachments A and B), double-bag ice in Ziploc baggies and place around container shoulders, and on top of absorbent packing material (minimum of 8 pounds of ice for a medium-size cooler).
- Seal (i.e., tape or tie top in knot) large liner bag.
- The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment.
- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

#### **5.4.2 Determination of Shipping Classification for Hazardous Material Samples**

Samples not determined to be environmental samples, or samples known or expected to contain hazardous materials, must be considered hazardous material samples and transported according to the requirements listed below.

##### **5.4.2.1 Known Substances**

If the substance in the sample is known or can be identified, package, mark, label, and ship according to the specific instructions for that material (if it is listed) in the DOT Hazardous Materials Table, 49 CFR 172.101. (DOT Guide for shippers can be found in Attachment D of this document.)

To determine the proper shipping name, use the following steps to help locate the shipping name on the Hazardous Materials Table, DOT 49 CFR 172.101.

1. Look first for the chemical or technical name of the material, for example, ethyl alcohol. Note that many chemicals have more than one technical name, for example, perchloroethylene (not listed in 172.101) is listed as tetrachloroethylene (listed 172.101). It may be useful to consult a chemist for all possible technical names a material can have. If your material is not listed by its technical name, then . . .
2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed, then . . .
3. Look for a generic name based on end use. For example, Paint, n.o.s. or Fireworks, n.o.s. If a generic name based on end use is not listed, then . . .
4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then . . .

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5. You will have to use the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s. or Oxidizer, n.o.s.

#### 5.4.2.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT hazardous materials classification of a material having more than one hazard. This procedure is outlined in DOT Regulation 49 CFR 173.2a. (This can be found in Attachment C of this SOP.)

The correct shipping classification for an unknown sample is selected through a process of elimination, as outlined in DOT Regulation 49 CFR 172.101(c)(11). By using the provisions in this paragraph, the proper shipping name and description will be determined. A step-by-step guide is provided by the Department of Transportation (DOT) and can be found in Attachment D of this SOP.

#### 5.4.3 **Packaging and Shipping of Samples Classified as Flammable Liquid (or Solid)**

##### 5.4.3.1 Packaging

Applying the word "flammable" to a sample does not imply that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations.

1. Containerize sample as required (see Attachments A and B). To prevent leakage, fill container no more than 90 percent full. Seal lid with teflon tape or wire.
2. Complete sample label and attach securely to sample container.
3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag (e.g., Ziploc baggie), one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.
4. For soil jars, place sealed bag inside metal can (available from laboratory or laboratory supplier) and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.3.4.2, below. Single 1-gallon bottles do not need to be placed in metal cans.
5. Place one or more metal cans (or a single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans (or bottle) with noncombustible, absorbent cushioning materials for stability during transport. The absorbent material should be able to absorb the entire contents of the container. Mark container as indicated in Paragraph 2 below.

##### 5.4.3.2 Marking/Labeling

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):
  - Laboratory name and address.

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- Proper shipping name from the hazardous materials table (DOT Regulation CFR 49 172.101). Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325." This will include packing group (see Section 5.3.4.2, No. 2.)

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. If identified, the name of the specific material is listed before the category (for example, Acetone, Flammable Liquid), followed by its appropriate UN number found in the DOT Hazardous Materials table (49 CFR 172.101).

2. Determine packing group. The packing group is part of the proper shipping name and must be included on the shipping papers in the description section.

- I. Most Hazardous
- II. Medium Hazard
- III. Least Hazardous

The packing group will be listed in the hazardous materials table, column 5.

3. Place all information on outside shipping container as on can (or bottle), specifically:

- Proper shipping name
- UN or NA number
- Proper label(s)
- Addressee and sender

Place the following labels on the outside shipping container: "Cargo Aircraft Only" and DOT label such as: "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the Flammable Solid has not been exposed to a wet environment. "Laboratory Samples" and "THIS SIDE UP" or "THIS END UP" shall also be marked on the top of the outside container, and upward-pointing arrows shall be placed on all four sides of the container.

#### 5.4.3.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement. Provide the following information in the order listed (one form may be used for more than one exterior container):

- Proper shipping name. (Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325 Packing Group I, II, III").
- "Limited Quantity" (or "Ltd. Qty."). (See No. 3, below.)
- "Cargo Aircraft Only."
- Net weight (wt) or net volume (vol), just before or just after "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s.," by item, if more than one metal can is inside an exterior container.
- "Laboratory Samples" (if applicable).



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2. Include Chain-of-Custody Record, properly executed in outside container; use custody seals.

3. "Limited Quantity" means the maximum amount of a hazardous material for which there is a specific labeling or packaging exception (DOT CFR 49 171.8). This may mean that packages are exempted from labeling requirements. To determine if your sample meets the Limited Quantity Exception, refer to DOT Regulation CFR 49 Subpart C 173.50 through 173.156. First, determine the proper classification and shipping name for the material; then refer to the exception requirements for that particular class of material beginning with 173.50.

Example: "Flammable Liquid n.o.s. UN1993 Packing Group 1." The outer package can weigh no more than 66 pounds gross weight. The inner package or container can weigh no more than 0.1 gallon net capacity for each container.

To determine whether the material can be shipped as a "Limited Quantity," you must check the specific requirement for that class of material.

#### 5.4.3.4 Transportation

1. The majority of unknown hazardous substance samples will be classified as flammable liquids. The samples will be transported by rented or common carrier truck, railroad, or express overnight package services. Do not transport samples on any passenger-carrying air transport system, even if the system has cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that carry only cargo. If unsure of what mode of transportation to use, consult the FOL or Project Manager.
2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be followed.
3. Use the hazardous materials shipping check list (Attachment E) as a guidance to ensure that all sample-handling requirements are satisfied.
4. In some cases, various materials may react if they break during shipment. To determine if you are shipping such materials, refer to the DOT compatibility chart in Attachment F.

#### 5.5 Shipment of Lithium Batteries

Monitoring well data are analyzed using either the Hermit SE 1000 or the Hermit SE 2000 environmental data logger. These instruments are powered by lithium batteries. The Department of Transportation has determined that lithium batteries are a hazardous material and are to be shipped using the following information:

<sup>1</sup> Note: If you are unsure as how to ship the sample (hazardous or environmental sample), contact the FOL or Project Manager so that a decision can be made as to the proper shipping practices. The DOT penalties for improper shipment of a hazardous material are stringent and may include a prison term for intentional violations.

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- Product Designation
  - Hermit SE 1000
  - Hermit SE 2000
- DOT Proper Shipping Name
  - Lithium batteries, contained in equipment, UN3091
- Classification or Division
  - Class 9

Shipment of equipment containing lithium batteries must be accompanied by shipping papers completed as indicated in Attachment G. The instrument will be shipped by Federal Express as a Hazardous Material. Place the instrument in the same container in which it was received. This container or case is a DOT-approved shipping container. For Federal Express procedures to ship hazardous materials, call 1-800-238-5355, extension 922-1666. In most cases, the return shipping papers and DOT labels will be shipped to you from the company warehouse or the vendor. An example of the types of labels used for shipment and the wording are shown in Attachment G. These labels will be attached to the outside container with the following wording:

- Lithium Batteries Contained in Equipment
  - UN-3091
  - Shipped Under CA-9206009

## 6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. APHA, Washington, D.C.

U.S. Department of Transportation, 1993. Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U.S. EPA-EMSL, Cincinnati, Ohio.

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## ATTACHMENT A

### GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration	Container <sup>(1)</sup>	Sample Size	Preservation <sup>(2)</sup>	Holding Time <sup>(2)</sup>
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#### WATER

Organics (GC&GC/MS)	VOC Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to $\leq 2$	14 days <sup>(8)</sup>
	Extractables SVOCs and pesticide/PCBs (Low)	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticide/PCBs (Medium)	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals Low	High-density polyethylene	1 L	HNO <sub>3</sub> to pH $\leq 2$	6 months (Hg-28 days)
	Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide Low	High-density polyethylene	1 L	NaOH to pH > 12	14 days
	Cyanide Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	14 days

#### SOIL

Organics (GC&GC/MS)	VOC	Wide-mouth glass with teflon liner	2 x 4 oz.	Cool to 4°C	14 days
	Extractables SVOCs and pesticides/PCBs (Low)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticides/PCBs (Medium)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium	Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/ Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All	Wide-mouth glass	4 oz.	None	7 days until extraction; 40 days after extraction
TCLP	All	Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction

#### AIR

Volatile Organics	Low/Medium	Charcoal tube – 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended
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<sup>(1)</sup> All glass containers should have Teflon cap liners or septa.

<sup>(2)</sup> See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

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## ATTACHMENT B

### ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container <sup>(1)</sup>	Preservation <sup>(2)(3)</sup>	Maximum Holding Time <sup>(4)</sup>
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#### INORGANIC TESTS:

Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid <sup>(5)</sup>	14 days <sup>(6)</sup>
Fluoride	P	None required	28 days
Hardness	P, G	HNO <sub>3</sub> to pH 2; H <sub>2</sub> SO <sub>4</sub> to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

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ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,  
AND HOLDING TIMES  
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Parameter Number/Name	Container <sup>(1)</sup>	Preservation <sup>(2)(3)</sup>	Maximum Holding Time <sup>(4)</sup>
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**INORGANIC TESTS (Cont'd):**

Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours

**METALS:<sup>(7)</sup>**

Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO <sub>3</sub> to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO <sub>3</sub> to pH 2	6 months

**ORGANIC TESTS:<sup>(8)</sup>**

Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> HCl to pH 2 <sup>(9)</sup>	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> adjust pH to 4-5 <sup>(10)</sup>	14 days
Phenols <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
Benzidines <sup>(11), (12)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction <sup>(13)</sup>
Phthalate esters <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines <sup>(11), (14)</sup>	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
PCBs <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> ; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs) <sup>(11), (14)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> ; store in dark	7 days until extraction; 40 days after extraction
Haloethers <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF) <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4°C; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction

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**ATTACHMENT B  
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,  
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PAGE THREE**

Parameter Number/Name	Container <sup>(1)</sup>	Preservation <sup>(2)(3)</sup>	Maximum Holding Time <sup>(4)</sup>
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**RADIOLOGICAL TESTS:**

1-5 Alpha, beta and radium	P, G	HNO <sub>3</sub> to pH 2	6 months
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- (1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
- (2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
- (3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
- (4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
- (5) Should only be used in the presence of residual chlorine.
- (6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
- (7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
- (8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
- (9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
- (10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
- (11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
- (12) If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
- (13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
- (14) For the analysis of diphenylnitrosamine, add 0.008% Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> and adjust pH to 7-10 with NaOH within 24 hours of sampling.
- (15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.

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### ATTACHMENT C

#### DOT HAZARDOUS MATERIAL CLASSIFICATION (49 CFR 173.2a)

1. Radioactive material (except a limited quantity)
2. Division 2.3, Poisonous Gases
3. Division 2.1, Flammable Gas
4. Division 2.2, Nonflammable gas
5. Division 6.1, Poisonous Liquids, Packing Group 1 (poison by inhalation only)
6. Division 4.2, Pyrophoric Material
7. Division 4.1, Self-Reactive Material
8. Class 3, Flammable Liquids\*
9. Class 8, Corrosive Material
10. Division 4.1, Flammable Solid\*
11. Division 4.2, Spontaneously Combustible Materials\*
12. Division 4.3, Dangerous When Wet Materials\*
13. Division 5.1, Oxidizers\*
14. Division 6.1, Poisonous Liquids or Solids (other than Packing Group 1)\*
15. Combustible liquid
16. Class 9. Miscellaneous Hazardous Materials

\* If a material has or meets the criteria for more than one hazard class, use the precedence of hazardous table on the following page for Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1. The following table ranks those materials that meet the definition of Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1.

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## ATTACHMENT C (Continued)

## PRECEDENCE OF HAZARD TABLE

(Hazard Class and Packing Group)

Class	Packing Group	4.2	4.3	5.1 I <sup>(a)</sup>	5.1 II <sup>(a)</sup>	5.1 III <sup>(a)</sup>	6.1 I (Dermal)	6.1 I (Oral)	6.1 II	6.1 III	8 I (Liquid)	8 I (Solid)	8 II (Liquid)	8 II (Solid)	8 III (Liquid)	8 III (Solid)
3	I						3	3	3	3	3	(c)	3	(c)	3	(c)
3	II						3	3	3	3	8	(c)	3	(c)	3	(c)
3	III						6.1	6.1	6.1	3 <sup>(d)</sup>	8	(c)	8	(c)	3	(c)
4.1	II <sup>b</sup>	4.2	4.3	5.1	4.1	4.1	6.1	6.1	4.1	4.1	(c)	8	(c)	4.1	(c)	4.1
4.1	III <sup>b</sup>	4.2	4.3	5.1	4.1	4.1	6.1	6.1	6.1	4.1	(c)	8	(c)	8	(c)	4.1
4.2	II		4.3	5.1	4.2	4.2	6.1	6.1	4.2	4.2	(c)	8	(c)	4.2	(c)	4.2
4.2	III		4.3	5.1	4.2	4.2	6.1	6.1	6.1	4.2	(c)	8	(c)	8	(c)	4.2
4.3	I			5.1	4.3	4.3	6.1	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
4.3	II			5.1	4.3	4.3	6.1	4.3	4.3	4.3	8	8	8	4.3	4.3	4.3
4.3	III			5.1	4.3	4.3	6.1	6.1	6.1	4.3	8	8	8	8	4.3	4.3
5.1	I <sup>a</sup>						5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
5.1	II <sup>a</sup>						6.1	5.1	5.1	5.1	8	8	8	5.1	5.1	5.1
5.1	III <sup>a</sup>						6.1	6.1	6.1	5.1	8	8	8	8	5.1	5.1
6.1	I, Dermal										8	6.1	6.1	6.1	6.1	6.1
6.1	I, Oral										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Inhalation										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Dermal										8	6.1	8	6.1	6.1	6.1
6.1	II, Oral										8	8	8	6.1	6.1	6.1
6.1	III										8	8	8	8	8	8

(a) There are at present no established criteria for determining Packing Groups for liquids in Division 5.1. At present, the degree of hazard is to be assessed by analogy with listed substances, allocating the substances to Packing Group I, Great; Group II, Medium; or Group III, Minor Danger.

(b) Substances of Division 4.1 other than self-reactive substances.

(c) Denotes an impossible combination.

(d) For pesticides only, where a material has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard is Division 6.1, Packing Group III.



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## ATTACHMENT D

### GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

**USE OF GUIDE** - This guide is presented as an aid to shippers of hazardous materials. It does not contain or refer to all of the DOT requirements for shipping hazardous materials. For specific details, refer to all of the DOT requirements for shipping hazardous materials, as provided in the Code of Federal Regulations (CFR), Title 49, Transportation, Parts 100-199.

The following is offered as a step-by-step procedure to aid in compliance with the applicable DOT regulations.

**STEP 1 - DETERMINE THE PROPER SHIPPING NAME.** The shipper must determine the proper shipping name of the materials as listed in the Hazardous Materials Table, 49 CFR 172.101, Column (2).

**STEP 2 - DETERMINE THE HAZARD CLASS OR CLASSES.**

- Refer to the Table, 49 CFR 172.101, Column (3), and locate the hazard class of the material.
- If more than one class is shown for the proper shipping name, determine the proper class by definition.
- If the materials have more than one hazard, classify the material based on the order of hazards in 49 CFR 173.2.

**STEP 3 - SELECT THE PROPER IDENTIFICATION NUMBERS.**

- Refer to the Table, 49 CFR 172.101, Column (3a), and select the Identification Number (ID) that corresponds to the proper shipping name and hazard class.
- Enter the ID number(s) on the shipping papers and display them, as required, on packagings, placards and/or orange panels.

**STEP 4 - DETERMINE THE MODE(S) OF TRANSPORT TO ULTIMATE DESTINATION.**

- As a shipper, you must assure yourself that the shipment complies with various modal requirements.
- The modal requirements may affect the following: (1) Packaging; (2) Quantity per Package; (3) Marking; (4) Labeling; (5) Shipping Papers; and (6) Certification.

**STEP 5 - SELECT THE PROPER LABEL(S) AND APPLY AS REQUIRED.**

- Refer to the Table, 49 CFR 172.101, Column (4) for required labels.
- For details on labeling refer to (1) Additional Labels, 49 CFR 172.402; (2) Placement of Labels, 49 CFR 172.406; (3) Packagings (Mixed or Consolidated), 49 CFR 172.404(a) and (h); (4) Packages Containing Samples, 49 CFR 172.402(h); (5) Radioactive Materials, 49 CFR 172.403; and (6) Authorized Label Modifications, 49 CFR 172.405.

**STEP 6 - DETERMINE AND SELECT THE PROPER PACKAGES.**

- Refer to the Table, 49 CFR 172.101, Column (5a) for exceptions and Column (5b) for specification packagings. Consider the following when selecting an authorized package: Quantity per Package; Cushioning Material, if required; Proper Closure and Reinforcement; Proper Pressure; Outage; etc., as required.
- If packaged by a prior shipper, make sure the packaging is correct and in proper condition for transportation.

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**ATTACHMENT D (Continued)**  
**GUIDE FOR HAZARDOUS MATERIALS SHIPPERS**

**STEP 7 - MARK THE PACKAGING (INCLUDING OVERPACKS).**

- a. Apply the required markings (49 CFR 172.300); Proper shipping name and ID number, when required (49 CFR 172.301); Name and address of Consignee or Consignor (49 CFR 172.306).
- b. For details and other required markings, see 49 CFR 172.300 through 172.338.

**STEP 8 - PREPARE THE SHIPPING PAPERS.**

- a. The basic requirements for preparing shipping papers include Proper Shipping Name; Hazard Class; ID Number; Total Quantity; Shipper's Certification; and Emergency Response Telephone Number.
- b. Make all entries on the shipping papers using the information required and in proper sequence (49 CFR 172.202).

**STEP 9 - CERTIFICATION.**

- a. Each shipper must certify by printing (manually or mechanically) on the shipping papers that the materials being offered for shipment are properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable DOT Regulations (49 CFR 172.202).

**STEP 10 - LOADING, BLOCKING, AND BRACING.** When hazardous materials are loaded into the transport vehicle or freight container, each package must be loaded, blocked, and braced in accordance with the requirements for mode of transport.

- a. If the shipper loads the freight container or transport vehicle, the shipper is responsible for the proper loading, blocking, and bracing of the materials.
- b. If the carrier does the loading, the carrier is responsible.

**STEP 11 - DETERMINE THE PROPER PLACARD(S).** Each person who offers hazardous materials for transportation must determine that the placarding requirements have been met.

- a. For Highway, unless the vehicle is already correctly placarded, the shipper must provide the required placard(s) and required ID number(s) (49 CFR 172.506).
- b. For Rail, if loaded by the shipper, the shipper must placard the rail car if placards are required (49 CFR 172.508).
- c. For Air and Water shipments, the shipper has the responsibility to apply the proper placards.

**STEP 12 - HAZARDOUS WASTE/HAZARDOUS SUBSTANCE.**

- a. If the material is classed as a hazardous waste or hazardous substance, most of the above steps will be applicable.
- b. Pertinent Environmental Protection Agency regulations are found in the Code of Federal Regulations, Title 40, Part 262.

**As a final check and before offering the shipment for transportation, visually inspect your shipment. The shipper should ensure that emergency response information is on the vehicle for transportation of hazardous materials.**

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## ATTACHMENT E

### HAZARDOUS MATERIALS SHIPPING CHECK LIST

#### PACKAGING

1. Check DOT 173.24 for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample and for chain-of-custody record.

#### SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful that all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Check that certification is signed by shipper.
8. Make certain driver signs for shipment.

#### RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.

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## ATTACHMENT F

### DOT SEGREGATION AND SEPARATION CHART

Class or Division	Notes	1.1-1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 gas Zone A*	2.3 gas Zone B*	3	4.1	4.2	4.3	5.1	5.2	6.1 liquids PG-I Zone A*	7	8 liquids only
Explosives . . . . . 1.1 and 1.2	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives . . . . . 1.3		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives . . . . . 1.4		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Very insensitive explosives . . . . . 1.5	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Extremely insensitive explosives . . . . . 1.6		*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable gases . . . . . 2.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-toxic, non-flammable gases . . . . . 2.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous gas - Zone A** . . . . . 2.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous gas - Zone B** . . . . . 2.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable liquids . . . . . 3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Flammable solids . . . . . 4.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spontaneously combustible materials . . . . . 4.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dangerous-when-wet materials . . . . . 4.3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oxidizers . . . . . 5.1	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Organic peroxides . . . . . 5.2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poisonous liquids PG I - Zone A** . . . . . 6.1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Radioactive materials . . . . . 7		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Corrosive liquids . . . . . 8		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

No entry means that the materials are compatible (have no restrictions).

X These materials may not be loaded, transported, or stored together in the same vehicle or facility.

O The materials may not be loaded, transported, or stored together in the same vehicle or facility unless they are separated for 4 feet on all sides.

\* Check the explosives compatibility chart in 49 CFR 179.848(f).

A Ammonium nitrate fertilizers may be stored with Division 1.1 materials.

\*\* Denotes inhalation hazardous for poisons; consult field team leader or project manager if you encounter a material in this class before shipment.

3224637861

Two completed and signed copies of this Declaration must be handed to the operator.

**WARNING**

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

**TRANSPORT DETAILS**

This shipment is within the limitations prescribed for:  
(delete non applicable)

~~HAZARDOUS~~  
~~HAZARDOUS~~  
~~HAZARDOUS~~

CARGO  
AIRCRAFT  
ONLY

Airport of Departure

Airport of Destination:

19CYS

Shipment type: (delete non-applicable)

NON-RADIOACTIVE

~~RADIOACTIVE~~**NATURE AND QUANTITY OF DANGEROUS GOODS****Dangerous Goods Identification**

Proper Shipping Name	Class or Division	UN or ID No.	Subsidiary Risk	Quantity and type of packing	Packing Inst.	Authorization
LITHIUM BATTERIES CONTAINED IN EQUIPMENT	9	UN3091		1 PLASTIC BOX X 55 GRAMS	912 II	PER CA-9206009

**Additional Handling Information**

1 HERMIT SERIES DATALOGGER X 55 GRAMS (11 GRAMS/CELL)

I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.

Name/Title of Signatory

Place and Date

Signature  
(see warning above)

Emergency Telephone Number (Required for US Origin or Destination Shipments)

800-535-5053

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

SAMPLE HANDLING

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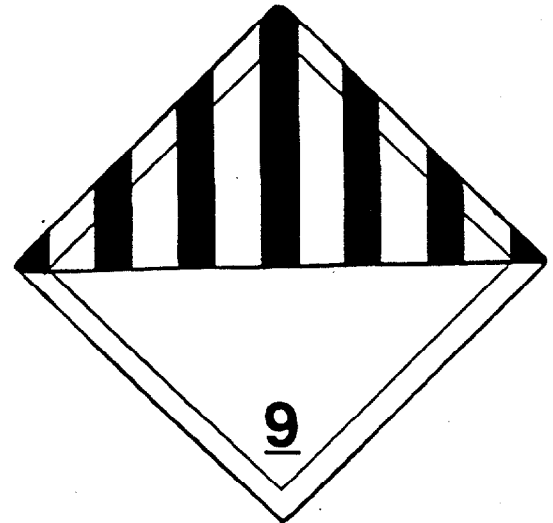
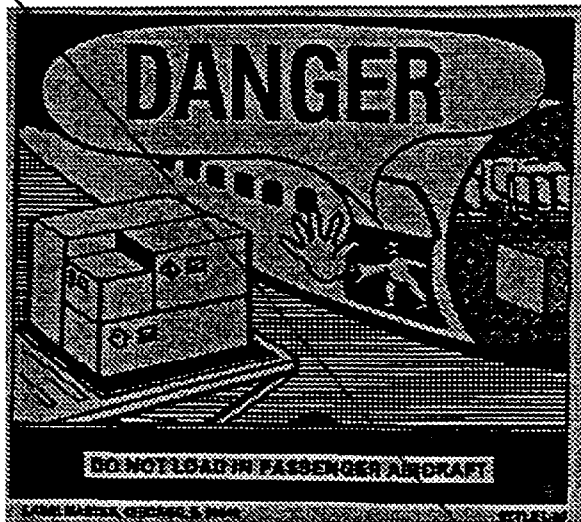
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ATTACHMENT G  
LITHIUM BATTERY SHIPPING PAPERS

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**ATTACHMENT G (CONTINUED)  
LITHIUM BATTERY SHIPPING PAPERS**



**LITHIUM BATTERIES CONTAINED  
IN EQUIPMENT.  
UN-3091.  
SHIPPED UNDER CA-9206009**



**BROWN & ROOT ENVIRONMENTAL**

# STANDARD OPERATING PROCEDURES

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Revision  
0

Applicability  
B&R Environmental, NE

Prepared  
Earth Sciences Department

Subject      FIELD DOCUMENTATION

Approved  
D. Senovich *ds*

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## **1.0 PURPOSE**

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Brown & Root Environmental field activities.

## **2.0 SCOPE**

Documents presented within this procedure (or equivalents) shall be used for all Brown & Root Environmental field activities, as applicable. Other or additional documents may be required by specific client contracts.

## **3.0 GLOSSARY**

None

## **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all forms used in site activities (i.e., records, field reports, and upon the completion of field work, the site logbook) in the project's central file.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate forms and field reports illustrated in this guideline (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time-frame.

## **5.0 PROCEDURES**

### **5.1 Site Logbook**

#### **5.1.1 General**

The site logbook is a hard-bound, paginated controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that onsite activities take place which involve Brown & Root Environmental or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

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The following information must be recorded on the cover of each site logbook:

- Project name
- Brown & Root Environmental project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the site notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used must be signed and dated. The site logbook must also be signed by the Field Operations Leader at the end of each day.

#### **5.1.2      Photographs**

When movies, slides, or photographs are taken of a site or any monitoring location, they must be numbered sequentially to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook. If possible, such techniques shall be avoided, since they can adversely affect the admissibility of photographs as evidence. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Adequate logbook notation and receipts must be compiled to account for routine film processing. Once processed, the slides or photographic prints shall be consecutively numbered and labeled according to the logbook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

#### **5.2              Site Notebooks**

Key field team personnel may maintain a separate dedicated notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate site notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a site notebook.

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### **5.3        Sample Forms**

A summary of the forms illustrated in this procedure is shown as the listing of Attachments in the Table of Contents for this SOP. Forms may be altered or revised for project-specific needs contingent upon client approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

#### **5.3.1        Sample Collection, Labeling, Shipment and Request for Analysis**

##### **5.3.1.1        Sample Log Sheet**

Sample Log Sheets are used to record specified types of data while sampling. Attachments B-1 to B-4 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

##### **5.3.1.2        Sample Label**

A typical sample label is illustrated in Attachment B-5. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source or are supplied from the laboratory subcontractor.

##### **5.3.1.3        Chain-of-Custody Record Form**

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One part of the completed COC form is retained by the field crew while the other two or three portions are sent to the laboratory. The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment B-6. A supply of these forms are purchased and stocked by the field department of the various Brown & Root Environmental offices. Alternately, COC forms supplied by the laboratory may be used. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the Brown & Root Environmental Project Manager). The COC form is signed and one of the remaining two parts are retained by the laboratory while the last part becomes part of the samples' corresponding analytical data package. Internal laboratory chain-of-custody procedures are documented in the Laboratory Quality Assurance Plan (LQAP).

##### **5.3.1.4        Chain-of-Custody Seal**

Attachment B-7 is an example of a custody seal. The Custody seal is also an adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The COC seals are signed and dated by the samplers and affixed across the opening edges of each cooler containing environmental samples. COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

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### **5.3.2 Geohydrological and Geotechnical Forms**

#### **5.3.2.1 Groundwater Level Measurement Sheet**

A groundwater level measurement sheet, shown in Attachment C-1 must be filled out for each round of water level measurements made at a site.

#### **5.3.2.2 Data Sheet for Pumping Test**

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

#### **5.3.2.3 Packer Test Report Form**

A packer test report form shown in Attachment C-3 must be completed for each well upon which a packer test is conducted following well installation.

#### **5.3.2.4 Summary Log of Boring**

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring (Attachment C-4) is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples or cuttings from the borehole (using HNU or OVA detectors), these results must be entered on the boring log (under the "Remarks" column) at the appropriate depth. The "Remarks" column can also be used to subsequently enter the laboratory sample number and the concentration of a few key analytical results. This feature allows direct comparison of contaminant concentrations with soil characteristics.

#### **5.3.2.5 Monitoring Well Construction Details Form**

A Monitoring Well Construction Details Form must be completed for every monitoring well piezometer or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-5 through C-9). Similar forms are used for flush-mount well completions. The Monitoring Well Construction Details Form is not a controlled document.

#### **5.3.2.6 Test Pit Log**

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-10) must be filled out by the responsible field geologist or sampling technician.

### **5.3.3 Equipment Calibration and Maintenance Form**

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of

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equipment require frequent calibration, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used.

#### **5.4      Field Reports**

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

##### **5.4.1      Weekly Status Reports**

To facilitate timely review by project management, Xeroxed copies of logbook/notebook entries may be made for internal use. To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required.

##### **5.4.2      Daily Activities Report**

###### **5.4.2.1      Description**

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

###### **5.4.2.2      Responsibilities**

It is the responsibility of the rig geologist to complete the DAR and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

###### **5.4.2.3      Submittal and Approval**

At the end of the shift, the rig geologist must submit the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

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## 6.0 ATTACHMENTS

Attachment A	TYPICAL SITE LOGBOOK ENTRY
Attachment B-1	EXAMPLE GROUNDWATER SAMPLE LOG SHEET
Attachment B-2	EXAMPLE SURFACE WATER SAMPLE LOG SHEET
Attachment B-3	EXAMPLE SOIL/SEDIMENT SAMPLE LOG SHEET
Attachment B-4	CONTAINER SAMPLE LOG SHEET FORM
Attachment B-5	SAMPLE LABEL
Attachment B-6	CHAIN-OF-CUSTODY RECORD FORM
Attachment B-7	CHAIN-OF-CUSTODY SEAL
Attachment C-1	EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET
Attachment C-2	EXAMPLE PUMPING TEST DATA SHEET
Attachment C-3	PACKER TEST REPORT FORM
Attachment C-4	EXAMPLE BORING LOG
Attachment C-5	EXAMPLE OVERBURDEN MONITORING WELL SHEET
Attachment C-5A	EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)
Attachment C-6	EXAMPLE CONFINING LAYER MONITORING WELL SHEET
Attachment C-7	EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL
Attachment C-8	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK
Attachment C-8A	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK (FLUSHMOUNT)
Attachment C-9	EXAMPLE TEST PIT LOG
Attachment D	EXAMPLE EQUIPMENT CALIBRATION LOG
Attachment E	EXAMPLE DAILY ACTIVITIES RECORD
Attachment F	FIELD TRIP SUMMARY REPORT

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**ATTACHMENT A  
TYPICAL SITE LOGBOOK ENTRY**

START TIME: \_\_\_\_\_ DATE: \_\_\_\_\_

SITE LEADER: \_\_\_\_\_  
PERSONNEL: \_\_\_\_\_

BROWN & ROOT ENV.

DRILLER

EPA

_____	_____	_____
_____	_____	_____
_____	_____	_____

WEATHER: Clear, 68°F, 2-5 mph wind from SE


ACTIVITIES:

1. Steam jenney and fire hoses were set up.
2. Drilling activities at well \_\_\_\_\_ resumes. Rig geologist was \_\_\_\_\_. See Geologist's Notebook, No. 1, page 29-30, for details of drilling activity. Sample No. 123-21-S4 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4-inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well \_\_\_\_\_.
3. Drilling rig No. 2 steam-cleaned at decontamination pit. Then set up at location of well \_\_\_\_\_.
4. Well \_\_\_\_\_ drilled. Rig geologist was \_\_\_\_\_. See Geologist's Notebook, No. 2, page \_\_\_\_\_ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well \_\_\_\_\_ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit \_\_\_\_\_.
8. Test pit \_\_\_\_\_ dug with cuttings placed in dump truck. Rig geologist was \_\_\_\_\_. See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit \_\_\_\_\_ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel off site, gate locked.

\_\_\_\_\_  
Field Operations Leader

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**ATTACHMENT B-1  
EXAMPLE GROUNDWATER SAMPLE LOG SHEET**

		<b>GROUNDWATER SAMPLE LOG SHEET</b>		Page ____ of ____	
Project Site Name: _____		Sample ID No.: _____			
Project No.: _____		Sample Location: _____			
<input type="checkbox"/> Domestic Well Data <input type="checkbox"/> Monitoring Well Data <input type="checkbox"/> Other Well Type: _____ <input type="checkbox"/> QA Sample Type: _____		Sampled By: _____ C.O.C. No.: _____			
<b>Sampling Data</b>					
Date: _____	pH: _____	S.C.: _____	Temp. (°C): _____	Turbidity: _____	Color: _____
Time: _____					
Method: _____					
<b>Purge Data</b>					
Date: _____	Volume	pH	S.C.	Temp. (°C)	Turbidity
Method: _____	Initial				
Monitor Reading (ppm):	1				
Well Casing Dia. & Material Type:	2				
	3				
Total Well Depth (TD):	4				
Static Water Level (WL):	5				
TD-WL (ft.) =					
One Casing Volume: (gal/L)					
Start Purge (hrs.):					
End Purge (hrs.):					
Total Purge Time (min):					
Total Amount Purged (gal/L):					
<b>Analysis</b>		<b>Preservative</b>		<b>Container Requirements</b>	
Observations/Notes:         					
<b>Circle if Applicable:</b>				<b>Signature(s):</b>	
MS/MSD	Duplicate ID No: _____				


TBD: To Be Determined





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**ATTACHMENT B-3  
EXAMPLE SOIL/SEDIMENT SINGLE SAMPLE LOG SHEET**

		<b>SOIL/SEDIMENT SINGLE SAMPLE LOG SHEET</b>		Page ____ of ____
Project Site Name: _____		Sample ID No.: _____		
Project No.: _____		Sample Location: _____		
<input type="checkbox"/> Surface Soil <input type="checkbox"/> Subsurface Soil <input type="checkbox"/> Sediment <input type="checkbox"/> Other _____ <input type="checkbox"/> QA Sample Type: _____		Sampled By: _____ C.O.C. No.: _____		
Sample Method:	Composite Sample Data			
Depth Sampled:	Sample	Time	Color/Description	
Sample Date and Time:				
<u>Type of Sample</u> <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab-Composite <input type="checkbox"/> High Concentration <input type="checkbox"/> Low Concentration				
	Grab Sample Data			
	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)		
Analysis:	Container Requirements	Collected (✓)	Map:	
Observations/Notes:				
Circle if Applicable: MS/MSD      Duplicate ID No:			Signature(s):	

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**ATTACHMENT B-4  
CONTAINER SAMPLE LOG SHEET FORM**



Brown & Root Environmental

Page \_\_\_\_ of \_\_\_\_

☐ Container Data

Case #: \_\_\_\_\_

By: \_\_\_\_\_

Project Site Name: \_\_\_\_\_ Project Site No. \_\_\_\_\_


Brown & Root Env. Source No. \_\_\_\_\_ Source Location: \_\_\_\_\_

Container Source		Container Description																																	
<input type="checkbox"/> Drum <input type="checkbox"/> Bung Top <input type="checkbox"/> Lever Lock <input type="checkbox"/> Bolted Ring <input type="checkbox"/> Other _____  <input type="checkbox"/> Bag/Sack <input type="checkbox"/> Tank <input type="checkbox"/> Other _____		Color: _____ Condition: _____ Markings: _____ Vol. of Contents: _____ Other: _____																																	
<b>Disposition of Sample</b> <input type="checkbox"/> Container Sampled <input type="checkbox"/> Container opened but not sampled. Reason: _____  <input type="checkbox"/> Container not opened. Reason: _____		<b>Sample Description</b> <table border="1"> <thead> <tr> <th></th> <th>Layer 1</th> <th>Layer 2</th> <th>Layer 3</th> </tr> </thead> <tbody> <tr> <td>Phase</td> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> <td><input type="checkbox"/> Sol. <input type="checkbox"/> Liq.</td> </tr> <tr> <td>Color</td> <td>_____</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>Viscosity</td> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> <td><input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H</td> </tr> <tr> <td>% of Total Volume</td> <td>_____</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>Other</td> <td>_____</td> <td>_____</td> <td>_____</td> </tr> </tbody> </table>					Layer 1	Layer 2	Layer 3	Phase	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	Color	_____	_____	_____	Viscosity	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	% of Total Volume	_____	_____	_____	Other	_____	_____	_____						
	Layer 1	Layer 2	Layer 3																																
Phase	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.	<input type="checkbox"/> Sol. <input type="checkbox"/> Liq.																																
Color	_____	_____	_____																																
Viscosity	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H	<input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H																																
% of Total Volume	_____	_____	_____																																
Other	_____	_____	_____																																
Monitor Reading:		<b>Type of Sample</b> <input type="checkbox"/> Grab <input type="checkbox"/> Low Concentration <input type="checkbox"/> Composite <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab-composite																																	
Sample Method:																																			
Sample Date & Time:		<table border="1"> <thead> <tr> <th>Sample Identification</th> <th>Organic</th> <th>Inorganic</th> </tr> </thead> <tbody> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> </tbody> </table>				Sample Identification	Organic	Inorganic																											
Sample Identification	Organic	Inorganic																																	
Sampled by:																																			
Signature(s):																																			
		Date Shipped																																	
Analysis:		Time Shipped																																	
		Lab																																	
		Volume																																	

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# ATTACHMENT B-5

## SAMPLE LABEL

 Brown & Root Environmental		PROJECT: _____
STATION LOCATION: _____		
DATE: ____ / ____ / ____		TIME: _____ hrs.
MEDIA:	WATER <input type="checkbox"/>	SOIL <input type="checkbox"/> SEDIMENT <input type="checkbox"/> _____ <input type="checkbox"/>
CONCENTRATION:	LOW <input type="checkbox"/>	MEDIUM <input type="checkbox"/> HIGH <input type="checkbox"/>
TYPE:	GRAB <input type="checkbox"/>	COMPOSITE <input type="checkbox"/>
ANALYSIS		PRESERVATION
VOA <input type="checkbox"/>	BNAs <input type="checkbox"/>	Cool to 4°C <input type="checkbox"/>
PCBs <input type="checkbox"/>	PESTICIDES <input type="checkbox"/>	HNO <sub>3</sub> to pH < 2 <input type="checkbox"/>
METALS: TOTAL <input type="checkbox"/>	DISSOLVED <input type="checkbox"/>	NaOH to pH > 12 <input type="checkbox"/>
CYANIDE <input type="checkbox"/>	_____ <input type="checkbox"/>	_____ <input type="checkbox"/>
Sampled by: _____		
Remarks: _____		

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**ATTACHMENT B-7**  
**CHAIN-OF-CUSTODY SEAL**

<b>CUSTODY SEAL</b> <hr/> <b>Date</b> <hr/> <b>Signature</b>	<b>CUSTODY SEAL</b> <hr/> <b>Date</b> <hr/> <b>Signature</b>
--	--









**ATTACHMENT C-3**

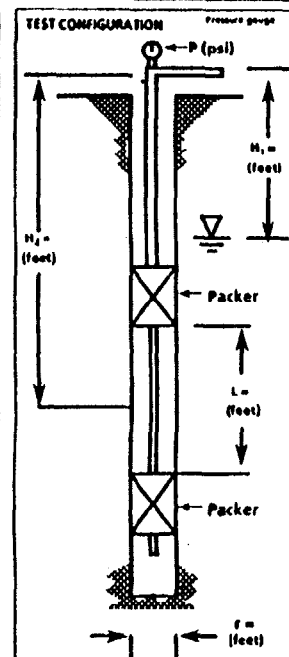
**PACKER TEST REPORT FORM**

PROJECT: \_\_\_\_\_ PROJECT NO.: \_\_\_\_\_ TEST NO.: \_\_\_\_\_ PAGE \_\_\_\_\_ OF \_\_\_\_\_  
BORING NO.: \_\_\_\_\_ CASING DEPTH: \_\_\_\_\_ CONTRACTOR: \_\_\_\_\_ STATIC WATER LEVEL \_\_\_\_\_  
TEST INTERVAL: \_\_\_\_\_ BY: \_\_\_\_\_ CHECKED: \_\_\_\_\_ PACKER PRESSURE \_\_\_\_\_

[illegible]

CP =  $(1/(2 \pi L)) \ln(U/r)$  (70,315 S)  
7.48 Gallons = 1 ft<sup>3</sup>  
1 psi = 2.31 ft head  
Remarks

- $H_1$  is used when the test length is below the water table.  
 $H_2$  is used when the test length is above the water table.



Length of level section in feet, <i>L</i>	Cp			
	Trimming bit size			
	1/4 (1.5")	3/8 (3.0")	1/2 (2.3")	5/8 (3")
1	31.000	20.500	25.000	23.500
2	19.000	10.500	10.000	15.500
5	9.000	9.500	8.000	8.000
8	6.000	6.500	6.000	5.500
10	5.700	5.000	5.000	4.900
15	5.100	5.000	5.000	5.000
20	5.250	5.100	5.000	5.000

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**LEGEND**  
**SOIL TERMS**

UNIFIED SOIL CLASSIFICATION (USCS)										
COARSE-GRAINED SOILS More Than Half of Material is LARGER Than No. 200 Sieve Size					FINE-GRAINED SOILS More Than Half of Material is SMALLER Than No. 200 Sieve Size					
FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES	FIELD IDENTIFICATION PROCEDURES (Including Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES	
					Identification Procedures on Fraction Smaller Than No. 40 Sieve Size					
						DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)		
GRAVELS (50% (+) > 1/4")	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	SILTS AND CLAYS Liquid Limit < 50	None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel sand mixtures, little or no fines.		Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.		Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.	SILTS AND CLAYS Liquid Limit > 50	Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
SANDS 50% (+) < 1/4")	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.		High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.		Medium to High	None to Very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	SM	Silty sands, poorly graded sand-silt mixtures.	HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			PT	Peat and other organic soils
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand-clay mixtures.						

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW GC, well graded gravel-sand mixture with clay binder. All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS	
DESIGNATION	STANDARD PENETRATION RESISTANCE BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS			
CONSISTENCY	UNC. COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

**ROCK TERMS**

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENNESS		
Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects	Descriptive Terms	Abbreviation	Spacing
Soft	Easily gouged	Crushes when pressed with hammer	Very Broken	(V. Br.)	0-2"
Medium Soft	Can be gouged	Breaks (one blow); crumbly edges	Broken	(Br.)	2"-1'
Medium Hard	Can be scratched	Breaks (one blow); sharp edges	Blocky	(Bl.)	1'-3"
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges	Massive	(M.)	3'-10"

**LEGEND:**

**SOIL SAMPLES - TYPES**  
 S-2" Split-Barrel Sample  
 ST-3" O.D. Undisturbed Sample  
 O - Other Samples, Specify in Remarks

**ROCK SAMPLES - TYPES**  
 K-MK (Conventional) Core (-2-1/8" O.D.)  
 Q-MQ (Wireline) Core (-1-7/8" O.D.)  
 Z - Other Core Sizes, Specify in Remarks

**WATER LEVELS**  
 12/10  
 12/10  
 Initial Level w/Date & Depth  
 Stabilized Level w/Date & Depth

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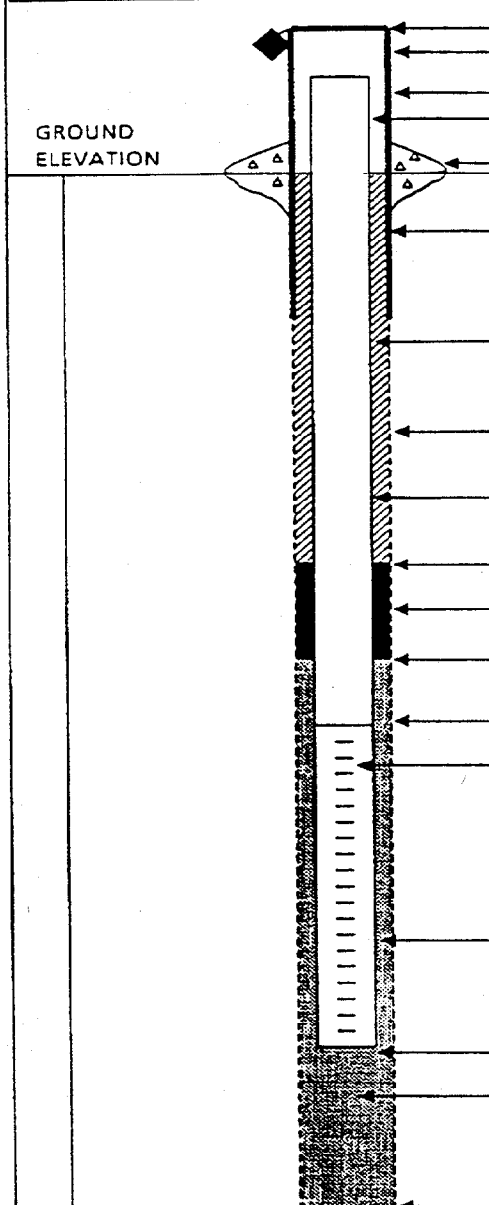
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**ATTACHMENT C-5  
EXAMPLE OVERBURDEN MONITORING WELL SHEET**

 <p><b>OVERBURDEN MONITORING WELL SHEET</b></p>		BORING NO.: _____
PROJECT _____ PROJECT NO. _____ ELEVATION _____ FIELD GEOLOGIST _____	LOCATION _____ BORING _____ DATE _____	DRILLER _____ DRILLING METHOD _____ DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : \_\_\_\_\_

ELEVATION OF TOP OF RISER PIPE : \_\_\_\_\_

STICK - UP TOP OF SURFACE CASING : \_\_\_\_\_

STICK - UP RISER PIPE : \_\_\_\_\_

TYPE OF SURFACE SEAL: \_\_\_\_\_

I.D. OF SURFACE CASING: \_\_\_\_\_

TYPE OF SURFACE CASING: \_\_\_\_\_

RISER PIPE I.D. \_\_\_\_\_

TYPE OF RISER PIPE: \_\_\_\_\_

BOREHOLE DIAMETER: \_\_\_\_\_

TYPE OF BACKFILL: \_\_\_\_\_

ELEVATION / DEPTH TOP OF SEAL: \_\_\_\_\_ / \_\_\_\_\_

TYPE OF SEAL: \_\_\_\_\_

DEPTH TOP OF SAND PACK: \_\_\_\_\_

ELEVATION / DEPTH TOP OF SCREEN: \_\_\_\_\_ / \_\_\_\_\_

TYPE OF SCREEN: \_\_\_\_\_

SLOT SIZE x LENGTH: \_\_\_\_\_

I.D. OF SCREEN: \_\_\_\_\_

TYPE OF SAND PACK: \_\_\_\_\_

ELEVATION / DEPTH BOTTOM OF SCREEN: \_\_\_\_\_ / \_\_\_\_\_


ELEVATION / DEPTH BOTTOM OF SAND PACK: \_\_\_\_\_ / \_\_\_\_\_

TYPE OF BACKFILL BELOW OBSERVATION WELL: \_\_\_\_\_

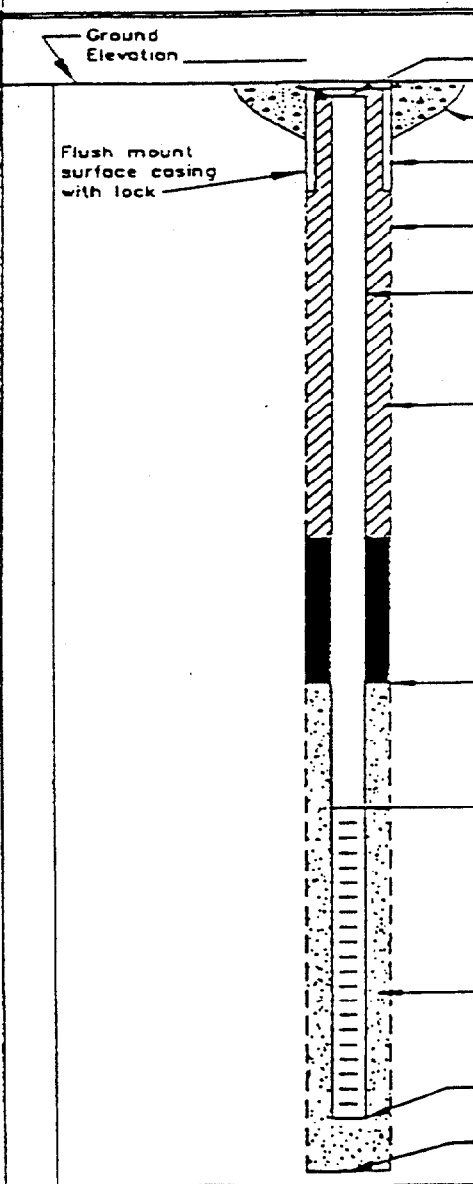
ELEVATION / DEPTH OF HOLE: \_\_\_\_\_ / \_\_\_\_\_

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**ATTACHMENT C-5A  
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)**

BORING NO.: _____		
 <h2 style="margin: 0;">MONITORING WELL SHEET</h2>		
PROJECT _____ PROJECT NO. _____ ELEVATION _____ FIELD GEOLOGIST _____	LOCATION _____ BORING _____ DATE _____	DRILLER _____ DRILLING METHOD _____ DEVELOPMENT METHOD _____



ELEVATION TOP OF RISER: \_\_\_\_\_

TYPE OF SURFACE SEAL: \_\_\_\_\_

TYPE OF PROTECTIVE CASING: \_\_\_\_\_

I.D. OF PROTECTIVE CASING: \_\_\_\_\_

DIAMETER OF HOLE: \_\_\_\_\_

TYPE OF RISER PIPE: \_\_\_\_\_

RISER PIPE I.D.: \_\_\_\_\_

TYPE OF BACKFILL/SEAL: \_\_\_\_\_

\_\_\_\_\_

DEPTH/ELEVATION TOP OF SAND: \_\_\_\_\_

DEPTH/ELEVATION TOP OF SCREEN: \_\_\_\_\_

TYPE OF SCREEN: \_\_\_\_\_

SLOT SIZE x LENGTH: \_\_\_\_\_

TYPE OF SAND PACK: \_\_\_\_\_

DIAMETER OF HOLE IN BEDROCK: \_\_\_\_\_

DEPTH/ELEVATION BOTTOM OF SCREEN: \_\_\_\_\_

DEPTH/ELEVATION BOTTOM OF SAND: \_\_\_\_\_


DEPTH/ELEVATION BOTTOM OF HOLE: \_\_\_\_\_

BACKFILL MATERIAL BELOW SAND: \_\_\_\_\_

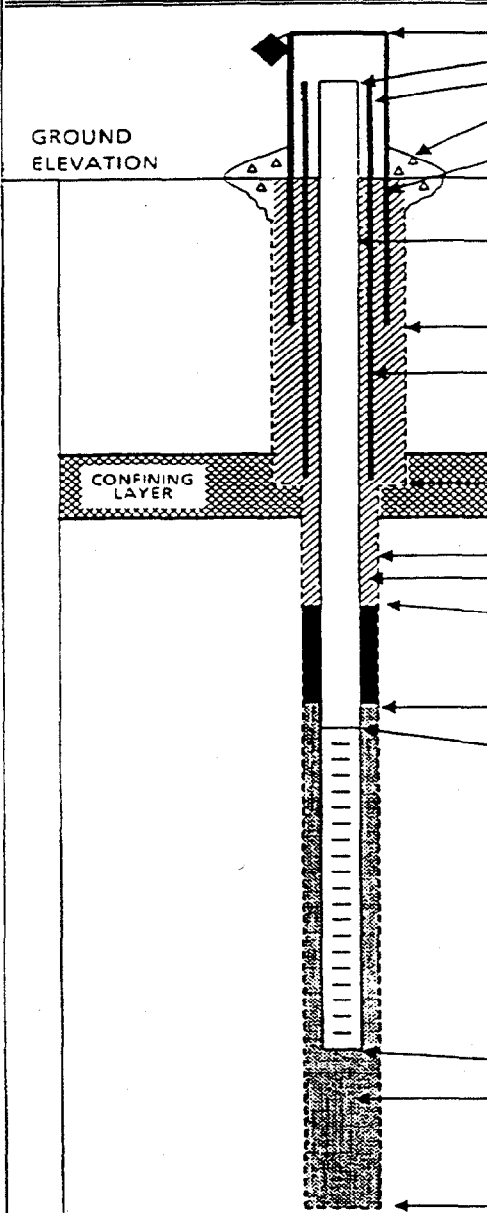
NOTES: 1. SEE VELD, 10/10/95, 10/10/95

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**ATTACHMENT C-6  
EXAMPLE CONFINING LAYER MONITORING WELL SHEET**

 <div style="display: inline-block; vertical-align: middle; text-align: center;"> <b>CONFINING LAYER MONITORING WELL SHEET</b> </div>		BORING NO.: _____
PROJECT _____ PROJECT NO. _____ ELEVATION _____ FIELD GEOLOGIST _____	LOCATION _____ BORING _____ DATE _____	DRILLER _____ DRILLING METHOD _____ DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : \_\_\_\_\_

ELEVATION OF TOP OF RISER PIPE: \_\_\_\_\_

ELEVATION TOP OF PERM. CASING: \_\_\_\_\_

TYPE OF SURFACE SEAL: \_\_\_\_\_

I.D. OF SURFACE CASING: \_\_\_\_\_

TYPE OF SURFACE CASING: \_\_\_\_\_

RISER PIPE I.D. \_\_\_\_\_

TYPE OF RISER PIPE: \_\_\_\_\_

BOREHOLE DIAMETER: \_\_\_\_\_

PERM. CASING I.D. \_\_\_\_\_

TYPE OF CASING & BACKFILL: \_\_\_\_\_

ELEVATION / DEPTH TOP CONFINING LAYER: \_\_\_\_\_

ELEVATION / DEPTH BOTTOM OF CASING: \_\_\_\_\_

ELEVATION / DEPTH BOT. CONFINING LAYER: \_\_\_\_\_

BOREHOLE DIA. BELOW CASING: \_\_\_\_\_

TYPE OF BACKFILL: \_\_\_\_\_

ELEVATION / DEPTH TOP OF SEAL: \_\_\_\_\_

TYPE OF SEAL: \_\_\_\_\_

DEPTH TOP OF SAND PACK: \_\_\_\_\_

ELEVATION/DEPTH TOP OF SCREEN: \_\_\_\_\_

TYPE OF SCREEN: \_\_\_\_\_

TYPE OF SAND PACK: \_\_\_\_\_

ELEVATION / DEPTH BOTTOM OF SCREEN: \_\_\_\_\_


ELEVATION / DEPTH BOTTOM OF SAND PACK: \_\_\_\_\_

TYPE OF BACKFILL BELOW OBSERVATION WELL: \_\_\_\_\_

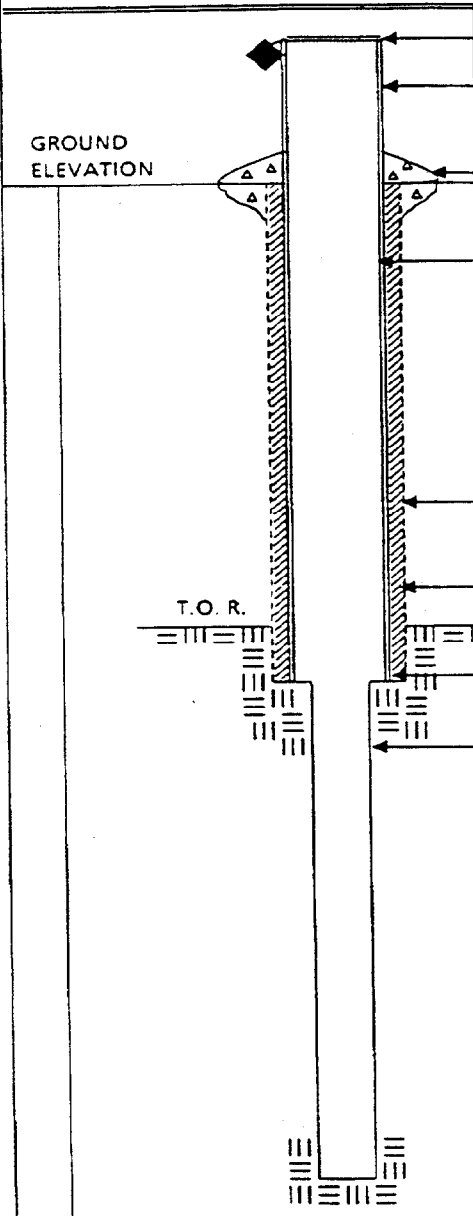
ELEVATION / DEPTH OF HOLE: \_\_\_\_\_

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**ATTACHMENT C-7**  
**EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL**


		BORING NO.: _____	
<b>BEDROCK MONITORING WELL SHEET OPEN HOLE WELL</b>			
PROJECT _____ PROJECT NO. _____ ELEVATION _____ FIELD GEOLOGIST _____		LOCATION _____ BORING _____ DATE _____	
		DRILLER _____ DRILLING METHOD _____ DEVELOPMENT METHOD _____	

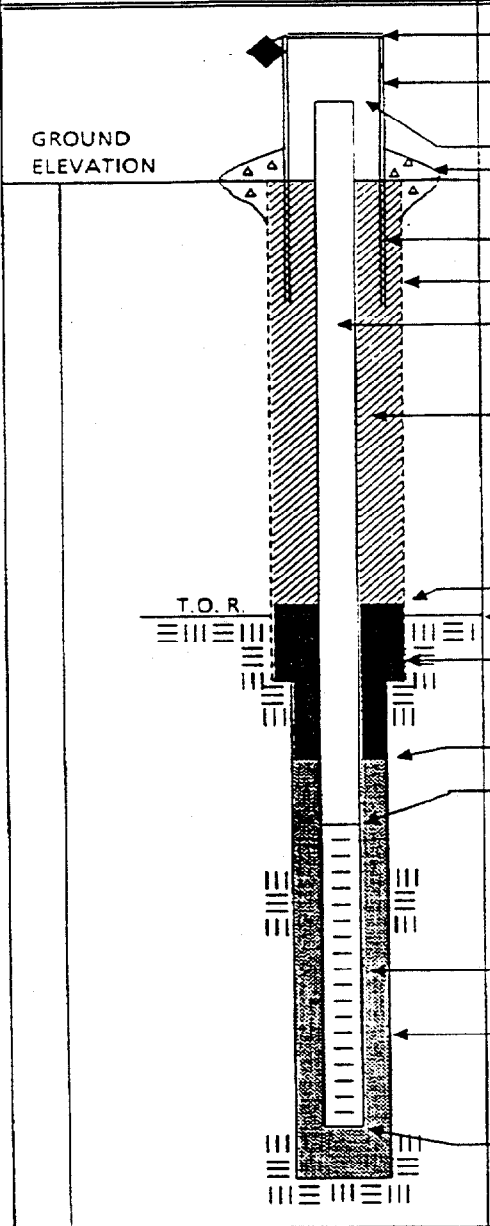
	ELEVATION OF TOP OF CASING:	_____
	STICK UP OF CASING ABOVE GROUND SURFACE:	_____
	TYPE OF SURFACE SEAL: _____	
	I.D. OF CASING: _____	
	TYPE OF CASING: _____	
	TEMP. / PERM.: _____	
	DIAMETER OF HOLE: _____	
	TYPE OF CASING SEAL: _____	
	DEPTH TO TOP OF ROCK: _____	
	DEPTH TO BOTTOM CASING: _____	
DIAMETER OF HOLE IN BEDROCK: _____		
DESCRIBE IF CORE / REAMED WITH BIT: _____ _____ _____		
DESCRIBE JOINTS IN BEDROCK AND DEPTH: _____ _____ _____		
ELEVATION / DEPTH OF HOLE: _____		

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**ATTACHMENT C-8**  
**EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK**

		<b>BORING NO.:</b> _____	
		<b>BEDROCK MONITORING WELL SHEET WELL INSTALLED IN BEDROCK</b>	
PROJECT _____	LOCATION _____	DRILLER _____	
PROJECT NO. _____	BORING _____	DRILLING METHOD _____	
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____	
FIELD GEOLOGIST _____			


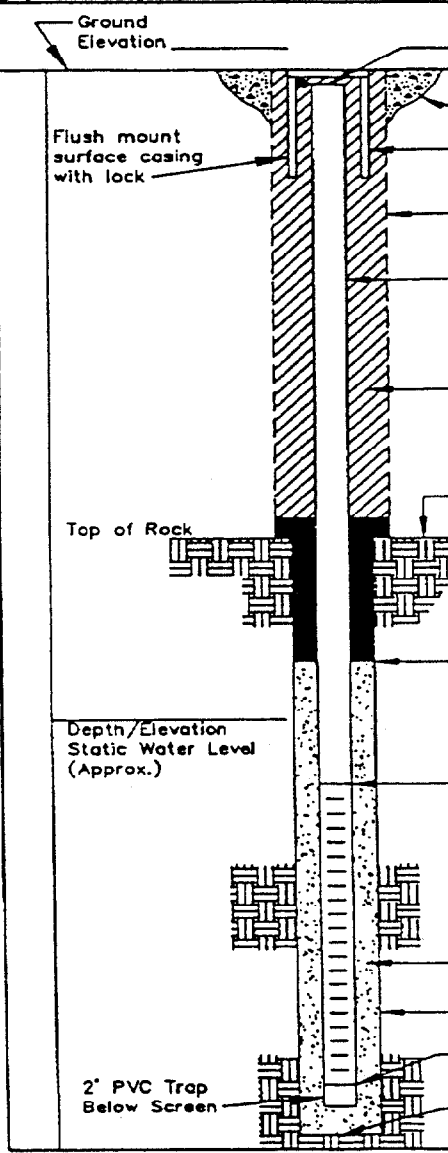
  

	ELEVATION OF TOP OF SURFACE CASING: _____
	STICK UP OF CASING ABOVE GROUND SURFACE: _____
	ELEVATION TOP OF RISER: _____
	TYPE OF SURFACE SEAL: _____
	I.D. OF SURFACE CASING: _____
	DIAMETER OF HOLE: _____
	RISER PIPE I.D.: _____
	TYPE OF RISER PIPE: _____
	TYPE OF BACKFILL: _____
	_____
	_____
	ELEVATION / DEPTH TOP OF SEAL: _____
	ELEVATION / DEPTH TOP OF BEDROCK: _____
	TYPE OF SEAL: _____
	_____
ELEVATION / DEPTH TOP OF SAND: _____	
ELEVATION / DEPTH TOP OF SCREEN: _____	
TYPE OF SCREEN: _____	
SLOT SIZE x LENGTH: _____	
I.D. SCREEN: _____	
TYPE OF SAND PACK: _____	
_____	
DIAMETER OF HOLE IN BEDROCK: _____	
CORE / REAM: _____	
_____	
ELEVATION / DEPTH BOTTOM SCREEN: _____	
ELEVATION / DEPTH BOTTOM OF HOLE: _____	



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**ATTACHMENT C-8A  
EXAMPLE BEDROCK MONITORING WELL SHEET  
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)**

 <div style="display: inline-block; text-align: right; margin-top: 0;">BORING NO.: _____</div> <h2 style="margin: 0;">BEDROCK MONITORING WELL SHEET</h2> <h3 style="margin: 0;">WELL INSTALLED IN BEDROCK</h3>																							
<table style="width: 100%; border: none;"> <tr> <td style="width: 33%; border-bottom: 1px solid black;">PROJECT: _____</td> <td style="width: 33%; border-bottom: 1px solid black;">LOCATION: _____</td> <td style="width: 33%; border-bottom: 1px solid black;">DRILLER: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">PROJECT NO.: _____</td> <td style="border-bottom: 1px solid black;">BORING: _____</td> <td style="border-bottom: 1px solid black;">DRILLING METHOD: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">ELEVATION: _____</td> <td style="border-bottom: 1px solid black;">DATE: _____</td> <td style="border-bottom: 1px solid black;">DEVELOPMENT METHOD: _____</td> </tr> <tr> <td colspan="3" style="border-bottom: 1px solid black;">FIELD GEOLOGIST: _____</td> </tr> </table>		PROJECT: _____	LOCATION: _____	DRILLER: _____	PROJECT NO.: _____	BORING: _____	DRILLING METHOD: _____	ELEVATION: _____	DATE: _____	DEVELOPMENT METHOD: _____	FIELD GEOLOGIST: _____												
PROJECT: _____	LOCATION: _____	DRILLER: _____																					
PROJECT NO.: _____	BORING: _____	DRILLING METHOD: _____																					
ELEVATION: _____	DATE: _____	DEVELOPMENT METHOD: _____																					
FIELD GEOLOGIST: _____																							
	<table style="width: 100%; border: none;"> <tr> <td style="border-bottom: 1px solid black;">ELEVATION TOP OF RISER: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF SURFACE SEAL: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF PROTECTIVE CASING: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">I.D. OF PROTECTIVE CASING: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">DIAMETER OF HOLE: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF RISER PIPE: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">RISER PIPE I.D.: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF BACKFILL/SEAL: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;"> </td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;"> </td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION TOP OF SAND: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;"> </td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION TOP OF SCREEN: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF SCREEN: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">SLOT SIZE x LENGTH: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">TYPE OF SAND PACK: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">DIAMETER OF HOLE IN BEDROCK: _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____</td> </tr> <tr> <td style="border-bottom: 1px solid black;">BACKFILL MATERIAL BELOW SAND: _____</td> </tr> </table>	ELEVATION TOP OF RISER: _____	TYPE OF SURFACE SEAL: _____	TYPE OF PROTECTIVE CASING: _____	I.D. OF PROTECTIVE CASING: _____	DIAMETER OF HOLE: _____	TYPE OF RISER PIPE: _____	RISER PIPE I.D.: _____	TYPE OF BACKFILL/SEAL: _____		DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____		DEPTH/ELEVATION TOP OF SAND: _____ / _____		DEPTH/ELEVATION TOP OF SCREEN: _____ / _____	TYPE OF SCREEN: _____	SLOT SIZE x LENGTH: _____	TYPE OF SAND PACK: _____	DIAMETER OF HOLE IN BEDROCK: _____	DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____	DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____	DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____	BACKFILL MATERIAL BELOW SAND: _____
ELEVATION TOP OF RISER: _____																							
TYPE OF SURFACE SEAL: _____																							
TYPE OF PROTECTIVE CASING: _____																							
I.D. OF PROTECTIVE CASING: _____																							
DIAMETER OF HOLE: _____																							
TYPE OF RISER PIPE: _____																							
RISER PIPE I.D.: _____																							
TYPE OF BACKFILL/SEAL: _____																							
DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____																							
DEPTH/ELEVATION TOP OF SAND: _____ / _____																							
DEPTH/ELEVATION TOP OF SCREEN: _____ / _____																							
TYPE OF SCREEN: _____																							
SLOT SIZE x LENGTH: _____																							
TYPE OF SAND PACK: _____																							
DIAMETER OF HOLE IN BEDROCK: _____																							
DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____																							
DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____																							
DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____																							
BACKFILL MATERIAL BELOW SAND: _____																							

ACFILE: 1670\GEOLOGY\BEDROCK.DWG



## ATTACHMENT D

### EXAMPLE EQUIPMENT CALIBRATION LOG



## EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME / MODEL : \_\_\_\_\_

**JOB NAME :** \_\_\_\_\_

MANUFACTURER : \_\_\_\_\_

**JOB NUMBER :** \_\_\_\_\_

019611/P



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**ATTACHMENT F  
FIELD TRIP SUMMARY REPORT  
PAGE 1 OF 2**

**SUNDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**MONDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**TUESDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**WEDNESDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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**ATTACHMENT F  
PAGE 2 OF 2  
FIELD TRIP SUMMARY REPORT**

**THURSDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**FRIDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**SATURDAY**

Date: \_\_\_\_\_ Personnel: \_\_\_\_\_  
Weather: \_\_\_\_\_ Onsite: \_\_\_\_\_

Site Activities: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



**BROWN & ROOT ENVIRONMENTAL**

# STANDARD OPERATING PROCEDURES

Number  
SA-7.1

Page  
1 of 9

Effective Date  
03/01/96

Revision  
0

Applicability  
B&R Environmental, NE

Prepared  
Earth Sciences Department

Subject      DECONTAMINATION OF FIELD EQUIPMENT  
AND WASTE HANDLING

Approved  
D. Senovich

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## **1.0 PURPOSE**

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

## **2.0 SCOPE**

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

## **3.0 GLOSSARY**

None.

## **4.0 RESPONSIBILITIES**

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

## **5.0 PROCEDURES**

To ensure that analytical chemical results reflect actual contaminant concentrations present at sampling locations, the various drilling equipment and chemical sampling and analytical equipment used to acquire the environment sample must be properly decontaminated. Decontamination minimizes the potential for cross-contamination between sampling locations, and the transfer of contamination offsite.

### **5.1 Drilling Equipment**

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental samples. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens. Where the drilling rig is set to perform multiple borings at a single area of concern, the steam-cleaning of the drilling rig itself may be waived with proper approval. Downhole equipment, however, must always be steam-cleaned between borings. Where PVC well casings are to be installed, decontamination is not required if the manufacturer provides these casings in factory-sealed, protective, plastic sleeves (so long as the protective packaging is not compromised until immediately before use).

The steam cleaning area shall be designed to contain decontamination wastes and waste waters and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be



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provided which is connected to a holding facility. A shallow above-ground tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. Alternately, a lined sloped pad with a collection pump installed at the lower end may be permissible. The location of the steam cleaning area shall be onsite in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating drilling equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned, as practicable. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

## **5.2        Sampling Equipment**

### **5.2.1      Bailers and Bailing Line**

The potential for cross-contamination between sampling points through the use of a common bailer or its attached line is high unless strict procedures for decontamination are followed. For this reason, it is preferable to dedicate an individual bailer and its line to each sample point, although this does not eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures must be followed.

Before the initial sampling and after each successive sampling point, the bailer must be decontaminated. The following steps are to be performed when sampling for organic contaminants. Note: contract-specific requirements may permit alternative procedures.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush (may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds)
- Potable water rinse
- Rinse with 10 percent nitric acid solution \*
- Deionized water rinse

---

\* Due to the leaching ability of nitric acid on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb.

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- Acetone or methanol rinse (in some EPA Regions, isopropanol is used instead)
- Hexane rinse\*\*
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, acetone, methanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When isopropanol is used, the bailer must be thoroughly dry before using to acquire the next sample.

In general, specially purchased pre-cleaned disposable sampling equipment is not decontaminated (nor is an equipment rinsate blank collected) so long as the supplier has provided certification of cleanliness. If decontamination is performed on several bailers at once (i.e., in batches), bailers not immediately used may be completely wrapped in aluminum foil (shiny-side toward equipment) and stored for future use. When batch decontamination is performed, one equipment rinsate is generally collected from one of the bailers belonging to the batch before it is used for sampling.

It is recommended that clean, dedicated braided nylon or polypropylene line be employed with each bailer use.

## 5.2.2 Sampling Pumps

Most sampling pumps are low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated prior to initial use and after each use.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except that the 10 percent nitric acid solution is omitted. Each of the liquid fractions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes. For peristaltic pumps, the tubing is replaced rather than cleaned.

An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics (especially phthalate esters) into the water being sampled or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (listed in order of preference). Whenever possible, dedicated hoses should be used. It is preferable that these types of pumps not be used for sampling, only for purging.

## 5.2.3 Filtering Equipment

On occasion, the sampling plan may require acquisition of filtered groundwater samples. Field-filtering is addressed in SOP SA-6.1 and should be conducted as soon after sample acquisition as possible. To this end, three basic filtration systems are most commonly used: the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated or replaced before each use.

---

\*\* If sampling for pesticides, PCBs, or fuels.

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For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

#### **5.2.4 Other Sampling Equipment**

Field tools such as trowels and mixing bowls are to be decontaminated in the same manner as described above.

### **5.3 Field Analytical Equipment**

#### **5.3.1 Water Level Indicators**

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water
- Acetone or methanol rinse (unless otherwise directed by manufacturer)
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

#### **5.3.2 Probes**

Probes (e.g., pH or specific-ion electrodes, geophysical probes, or thermometers) which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise (e.g., dissolved oxygen probes). Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, (e.g., OVA equipment) the probe is self-cleaning when exposure to uncontaminated air is allowed and the housing can be wiped clean with paper-towels or cloth wetted with alcohol.

### **5.4 Waste Handling**

For the purposes of these procedures, contaminated materials are defined as any byproducts of field activities that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials and Personal Protection Equipment (PPE).

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during field activities will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure exclusively describes the technical methods used to control contaminated materials.

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The plan documents for site activities must include a description of control procedures for contaminated materials. This planning strategy must assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials can be dangerous and expensive. Until sample analysis is complete, it is assumed that all produced materials are suspected of contamination from hazardous chemicals and require containment.

## **5.5 Sources of Contaminated Materials and Containment Methods**

### **5.5.1 Decontamination Solutions**

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors must be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

### **5.5.2 Disposable Equipment**

Disposable equipment that could become contaminated during use typically includes PPE, rubber gloves, boots, broken sample containers, and cleaning-wipes. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment until disposed.

### **5.5.3 Drilling Muds and Well-Development Fluids**

Drilling muds and well-development fluids are materials that may be used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds that require containment. The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes (or number) of containment structures required. Since guesswork is involved, it is recommended that an slight excess of the estimated amount of containers required will be available.

Drilling muds are mixed and stored in what is commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling mud is withdrawn and pumped through hoses, down the drill pipe to the bit, and back up the hole to the settling section of the mud pit. In the settling section, the mud's velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the mud/fluid.

The mud pit may be either portable above-ground tanks commonly made of steel (which is preferred) or stationary in-ground pits as depicted in Attachment A. The above-ground tanks have a major advantage over the in-ground pits because the above-ground tanks isolate the natural soils from the

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contaminated fluids within the drilling system. These tanks are also portable and can usually be cleaned easily.

As the well is drilled, the cuttings that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for its next use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the lining material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling muds. The volume and weight of contaminated fluid will be determined by the method used for development. When a new well is pumped or bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

#### **5.5.4 Spill-Contaminated Materials**

A spill is always possible when containers of liquids are opened or moved. Contaminated sorbents and soils resulting from spills must be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

#### **5.6 Disposal of Contaminated Materials**

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, landfilling, treatment, and so on. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the containment structures should be specifically designed for that purpose.

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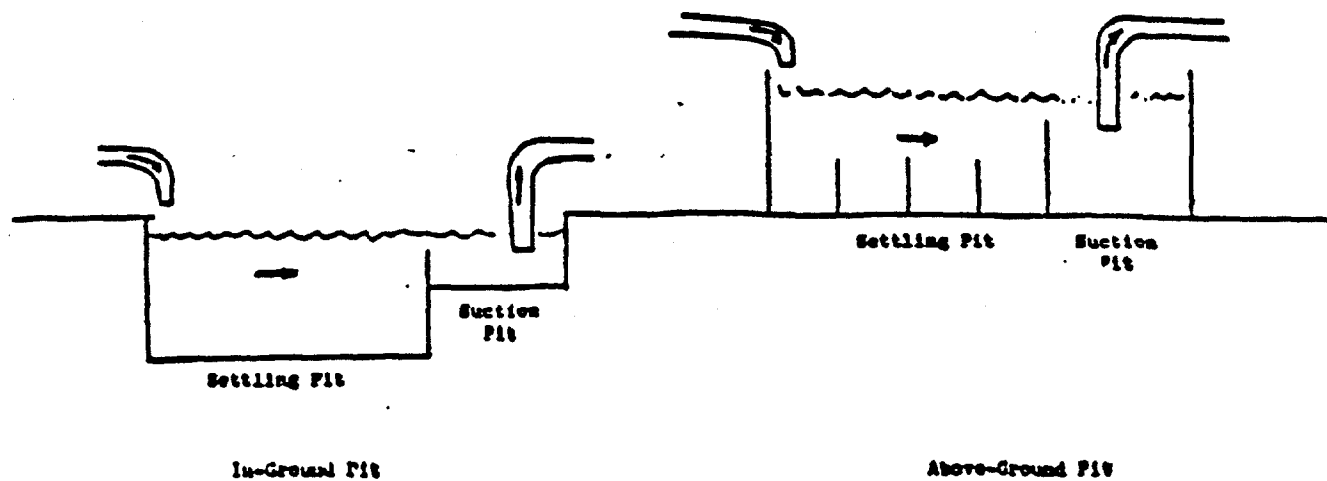
## **6.0 REFERENCES**

Brown & Root Environmental: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

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# ATTACHMENT A

## TWO TYPES OF MUD PITS USED IN WELL DRILLING



**USEPA REGION I**  
**LOW FLOW SAMPLING**



Matt -

**COPY FOR YOUR  
INFORMATION**

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SOP #: GW 0001  
Region I Low Stress  
(Low Flow) SOP  
Revision Number: 2  
Date: July 30, 1996  
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**U.S. ENVIRONMENTAL PROTECTION AGENCY  
REGION I**

**LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE  
FOR THE COLLECTION OF GROUND WATER SAMPLES  
FROM MONITORING WELLS**

**I. SCOPE & APPLICATION**

This standard operating procedure (SOP) provides a general framework for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). The SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation). However, this procedure is flexible and can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). For this the reader may wish to check: Cohen, R.M. and J.W. Mercer, 1993, DNAPL Site Evaluation; C.K. Smoley (CRC Press), Boca Raton, Florida and U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; Washington, DC (EPA/530-R-93-001).

The screen, or open interval of the monitoring well should be optimally located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screen, or open interval.

Use of trademark names does not imply endorsement by U.S.EPA but is intended only to assist in identification of a specific type of device.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

The mid-point of the saturated screen length (which should not exceed 10 feet) is used by convention as the location of the pump intake. However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permeability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Sampling and Analysis Plan must provide clear instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

Changes to this SOP should be proposed and discussed when the site Sampling and Analysis Plan is submitted for approval. Subsequent requests for modifications of an approved plan must include adequate technical justification for proposed changes. All changes and modifications must be approved before implementation in field.

## II. EQUIPMENT

### A. Extraction device

Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or Teflon).

Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).

The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling and are less easily controlled than the pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

### B. Tubing

Teflon or Teflon lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs. However, it should be used with caution when sampling for metals.

The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.

Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

C. Water level measuring device(s), capable of measuring to 0.01 foot accuracy (electronic "tape", pressure transducer). Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use

must include check measurements with a water level "tape" at the start and end of each record.

D. Flow measurement supplies (e.g., graduated cylinder and stop watch).

E. Interface probe, if needed.

F. Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

G. Indicator field parameter monitoring instruments - pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

H. Decontamination supplies (for example, non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).

I. Logbook(s), and other forms (for example, well purging forms).

J. Sample Bottles.

K. Sample preservation supplies (as required by the analytical methods).

L. Sample tags or labels.

M. Well construction data, location map, field data from last sampling event.

N. Well keys.

O. Site specific Sample and Analysis Plan/Quality Assurance Project Plan.

P. PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

### III. PRELIMINARY SITE ACTIVITIES

Check well for security damage or evidence of tampering, record pertinent observations.

Lay out sheet of clean polyethylene for monitoring and sampling equipment.

Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument and record the reading in the field logbook.

If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.

A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) be measured the day before, in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation. Note: procedures for collection of LNAPL and DNAPL samples are not addressed in this SOP.

### IV. PURGING AND SAMPLING PROCEDURE

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

#### 1. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. The Sampling and Analysis Plan should specify the sampling depth, or provide criteria for selection of intake depth for each well (see Section I). If possible keep the pump intake at least two

feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

## 2. Measure Water Level

Before starting pump, measure water level. If recording pressure transducer is used-initialize starting condition.

## 3. Purge Well

### 3a. Initial Low Stress Sampling Event

Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameter stabilize.

Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

### 3b. Subsequent Low Stress Sampling Events

After synoptic water level measurement round, check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). Perform purging operations as above.

### 4. Monitor Indicator Field Parameters

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:

- turbidity (10% for values greater than 1 NTU),
- DO (10%),
- specific conductance (3%),
- temperature (3%),
- pH ( $\pm 0.1$  unit),
- ORP/Eh ( $\pm 10$  millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.

The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

## 5. Collect Water Samples

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).

VOC samples should be collected first and directly into pre-preserve sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g. EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to assure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in ground water for human health risk calculations.



Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

#### 6. Post Sampling Activities

If recording pressure transducer is used, remeasure water level with tape.

After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event. However, it is recommended if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

#### V. DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below.

##### Procedure 1

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is

recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped.

Flush with distilled/deionized water. The final water rinse must not be recycled.

#### Procedure 2

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

#### **VI. FIELD QUALITY CONTROL**

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the ground water samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples shall be collected for each batch of samples (a batch

may not exceed 20 samples). Trip blanks are required for the VOC samples at a frequency of one set per VOC sample cooler.

Field duplicate.

Matrix spike.

Matrix spike duplicate.

Equipment blank.

Trip blank (VOCs).

Temperature blank (one per sample cooler).

Equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank will only include the pump in subsequent sampling rounds.

Collect samples in order from wells with lowest contaminant concentration to highest concentration. Collect equipment blanks after sampling from contaminated wells and not after background wells.

Field duplicates are collected to determine precision of sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

If split samples are to be collected, collect split for each analyte group in consecutive order (VOC original, VOC split, etc.). Split sample should be as identical as possible to original sample.

All monitoring instrumentation shall be operated in accordance with EPA analytical methods and manufacturer's operating instructions. EPA analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846 with exception of Eh, for which the manufacturer's instructions are to be followed. Instruments shall be calibrated at the beginning of each day. If a measurement falls outside the calibration range, the instrument should be re-calibrated so that all measurements fall within the calibration range. At the end of each day, check calibration to verify that instruments remained in calibration. Temperature measuring equipment, thermometers and thermistors, need not be calibrated to the above frequency. They should be checked for accuracy prior to field use according to EPA Methods and the manufacturer's instructions.

## VII. FIELD LOGBOOK

A field log shall be kept to document all ground water field monitoring activities (see attached example matrix), and record all of the following:

Well identification.

Well depth, and measurement technique.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, and clock time, at the appropriate time intervals; calculated or measured total volume pumped.

Well sampling sequence and time of each sample collection.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analysis.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

## VIII. DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, and whatever field logbook information is needed to allow for a full evaluation of data useability.

## Page of

[illegible]

1. Pump dial setting (for example: hertz, cycles/min, etc).
2.  $\mu$ Siemens per cm (same as  $\mu$ mhos/cm) at 25°C.
3. Oxidation reduction potential (stand in for Eh).

**APPENDIX C**  
**PUMP INFORMATION**

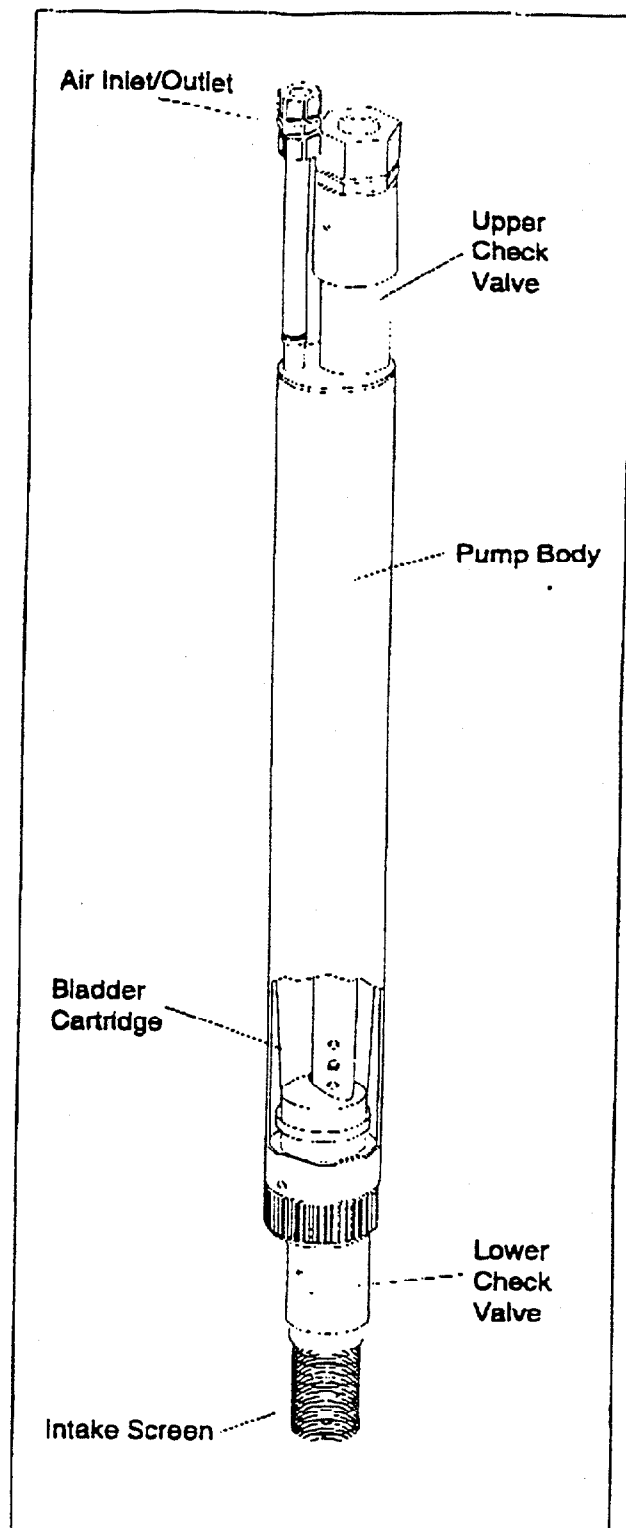
# MASTER-FLO

Ground Water Sampling Systems

## 57000 SERIES BLADDER PUMPS

MASTER-FLO dedicated bladder pumps meet rigid U.S.E.P.A. (Nov 93) requirements for ground water monitoring, while offering the highest flow rates of any bladder pump of equivalent size. This enhanced performance results from an offset center tube and check valves which produce a straight water path. The .5 inch path is larger than the .375 inch of conventional bladder pumps. The larger bore and unrestricted flow path combine to produce higher flow rates for purging and low, consistent flows for sampling.

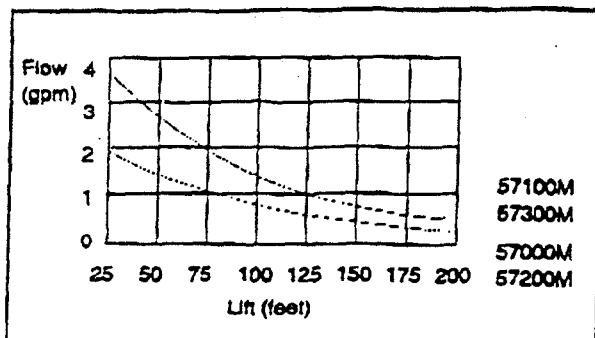
- Pump diameters for 2" (51 mm) and larger wells.
- Pumping rates up to 3 gpm (11.3 lpm) @ 45 ft. (13.7 m) in a 2" (51 mm) well...large air and water porting (.5 inch) enables faster pump/fill cycles; larger bladder than conventional bladder pumps permits more volume pumped per cycle. Flow rate can be reduced to less than 100 ml/min., as is recommended by the U.S.E.P.A. for sampling.
- EPA recommended materials including NSF rated PVC and Teflon®, or Type 316 Stainless Steel and Teflon®.
- Large water discharge porting reduces pressure gradients between the bladder and discharge tubing, lessening the potential for orifice outgassing that can compromise dissolved gas and VOC samples.
- Factory sealed, field replaceable, Teflon® bladder cartridges slip into place, without tools or clamps. Lifetime guarantee (When permanently installed).
- Withstands dry pumping.
- Easy installation by one person.
- Threaded pump intakes permit the use of intake drop tube extensions, booster pump applications, and other unique configurations.
- Type 316 Stainless Steel, .010 inch intake screens help protect bladders from sand.
- Contaminant free certification - all pumps are cleaned, lab tested and individually sealed in polyethylene bags.



**For applications assistance  
call 1-800-645-7654.**

# 57000 SERIES BLADDER PUMPS

## FLOW PERFORMANCE CURVES



### Notes:

1. Flow based on air operating pressure of 125 psi, air displacement rate of 3.5 scfm, and 15 feet of submergence.
2. Pumps utilize thermally bonded twin tubing having a air tube of 1/4" I.D. and a water discharge tube of 1/2" I.D.
3. Flow at any depth based on specific tubing length and free discharge to atmosphere.

## DESIGN SPECIFICATIONS

MODEL	MATERIAL	O.D. (in./mm.)	L (in./cm.)	WEIGHT (lbs./kg.)	CAPACITY (gal./L.)
*57000M	S.S./Teflon	1.66/42	44/112	4.6/2.09	0.14/0.55
57100M	S.S./Teflon	1.66/42	80/204	8.4/3.81	0.29/1.1
*57200M	PVC/Teflon	1.90/48	44/112	3.6/1.64	0.14/0.55
57300M	PVC/Teflon	1.90/48	80/204	6.3/2.86	0.29/1.1

\*Models 57000M and 57200M available for use with 3/8" I.D. water discharge tubing. Flow will be slightly less than shown on curve. Specify as Model 57000 or 57200.

## ENGINEERING SPECIFICATIONS

1. Pump Models 57000M/57100M shall have an O.D. of 1.66 inches (42 mm), with Models 57200M/57300M having an O.D. of 1.90 inches (48 mm), to permit use in 2" (51 mm) or larger wells.
2. The pump shall be a positive displacement bladder squeeze pump, whereby the drive air does not contact the sample.
3. The pump shall permit water to enter the interior of the bladder through a bottom check valve and air to enter the annulus between the pump body and bladder through an upper air inlet/outlet.
4. The pump shall not fill by suction assist or place a negative pressure on the sample.
5. The pump shall have a minimum 1/2" water discharge port, without restrictions, to eliminate dissolved gas loss due to orifice effects during sampling.
6. Models 57000M/57100M shall be constructed from electropolished, Type 316 Stainless Steel and Teflon. Models 57200M/57300M shall be constructed from NSF rated PVC and Teflon.
7. All internal pump components shall be of Teflon.
8. The pump shall employ a field replaceable, Teflon, factory sealed and tested bladder cartridge, to be installed without tools.
9. The pump shall withstand continuous operation at 200 psi (14 bars) without modification.
10. The pump shall be capable of lifting from 450 feet (135 m) without modification.
11. The pump shall be capable of dry pumping without damage.
12. The pump shall be equipped with a threaded intake to permit the use of a drop tube extension, booster pumps, and factory equipped, Type 316 Stainless Steel, .010" intake screen.

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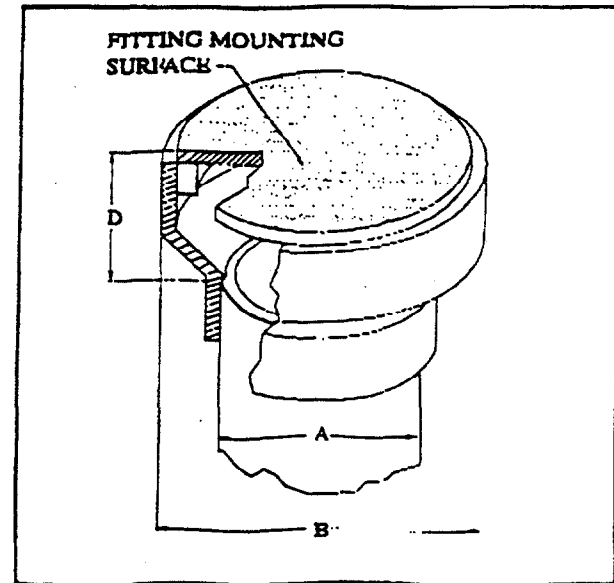


## DEDICATED WELLHEAD CLOSURES

### Bell Cap, Non-lockable

The non-lockable Bell Cap is available for 1.5 and 2-inch wells and is recommended when numerous fittings must be mounted to the closure plate. When using on the wells within a vault or protective casing, be sure that there is adequate vertical and diametral clearance for installation.

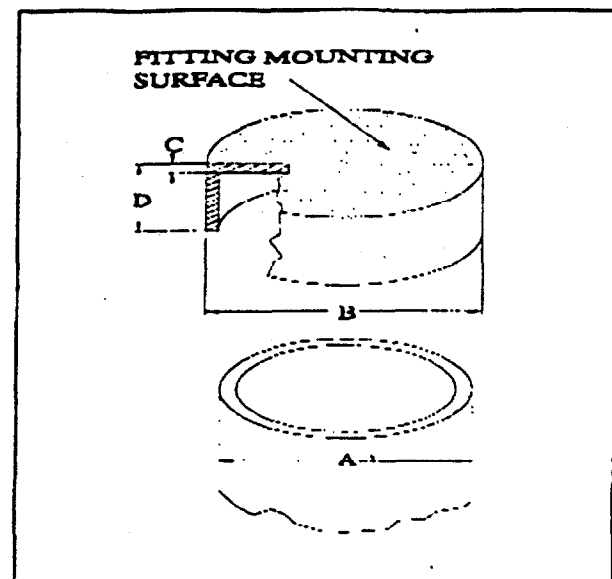
MODEL #	WELL STYLE SIZE	A	B	C
5492	1.5" Non-lockable Bell Cap	1.90	4.00	2.75
5493	2" Non-lockable Bell Cap	2.30	4.00	2.75



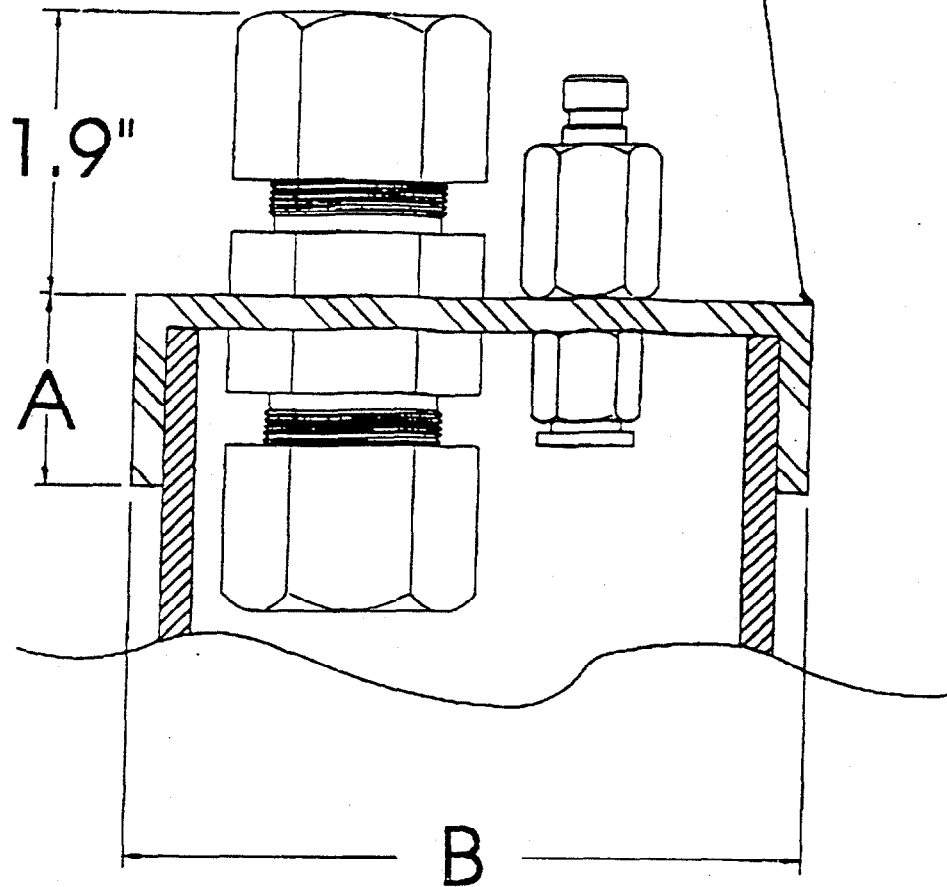
### Flat Cap, Non-lockable

This style closure is available for all size well casings (sizes larger than 4-inch may have a slightly domed top). It is recommended for use on wells inside protective casings or vaults where there is adequate clearance for the tube fittings between the top to the well casing and the lid of the protective casing.

MODEL #	WELL STYLE SIZE	A	B	C	D
5870	2" Non-lockable Flat Cap	2.38	2.70	0.25	1.80
5494	3" Non-lockable Flat Cap	3.50	4.00	0.25	1.85
5422	4" Non-lockable Flat Cap	4.50	5.00	0.25	2.30
5442	6" Non-lockable Flat Cap	6.62	7.25	0.25	3.35



# TOP OF CLOSURE



Model	Well Size	A	B
5870	2"	1.80"	2.70"
5422	4"	2.30"	5.00"

# MASTER-FLD

Ground Water Sampling Systems

## TUBING ASSEMBLY OPTIONS

GEOGUARD offers a variety of tubing options in either coaxial or bonded configurations. Material options of polyethylene, Teflon lined polyethylene, or pure Teflon® provide economy and chemical inertness. Coaxial tubing is utilized in well development and portable purging applications. Bonded tubing used with dedicated pumps eliminates the potential of interference with portable static water level measurement probes.

MODEL #	STYLE	MATERIAL	AIR TUBE I.D. X O.D. (IN/CM)	WATER TUBE I.D. X I.D. (IN/CM)	COMPATIBLE PUMP
5896	Bonded Twin	Polyethylene	.250 x .375/ 0.64 x 0.95	.375 x .500/ 0.95 x 1.27	5615 5635 57000 57200
5688	Bonded Twin	Polyethylene	.375 x .500/ 0.95 x 1.27	.625 x .750/ 1.59 x 1.91	5662 5952
5689	Bonded Twin	Polyethylene	.375 x .500/ 0.95 x 1.27	.375 x .500/ 0.95 x 1.27	5972 5973 5974 5975
5897	Bonded Twin	Teflon Lined Polyethylene	.250 x .375/ 0.64 x 0.95	.375 x .500/ 0.95 x 1.27	57000 5615 5635 57200 5625
5916	Bonded Twin	Pure Teflon	.250 x .375/ 0.64 x 0.95	.375 x .500/ 0.95 x 1.27	5645 57000
5090	Coaxial	Polyethylene	.625 x .750/ 1.59 x 1.91	.375 x .500/ 0.95 x 1.27	5602 5612 5622 5632
5170	Coaxial	Polyethylene	.625 x .875/ 1.59 x 2.22	.375 x .500/ 0.95 x 1.27	5612D 5632D
5822	Bonded Twin	Pure Teflon	.250 x .375/ 0.64 x 0.95	.500 x .625 1.27 x 1.59	57000M 57100M
5740	Bonded Twin	Teflon Lined Polyethylene	.250 x .375 0.64 x 0.95	.500 x .625 1.27 x 1.59	57000M 57100M 57200M 57300M
5741	Bonded Twin	Polyethylene	.250 x .375/ 0.64 x 0.95	.500 x .625/ 1.27 x 1.59	57000M 57100M 57200M 57300M
5878	Tri-Bond	Polyethylene	.375 x .500/ 0.95 x 1.27	.375 x .500/ 0.95 x 1.27	5634 56140
5879	Tri-Bond	Teflon Lined Polyethylene	.375 x .500/ 0.95 x 1.27	.375 x .500/ 0.95 x 1.27	5634 56140
5880	Tri-Bond	Pure Teflon	.375 x .500/ 0.95 x 1.27	.375 x .500/ 0.95 x 1.27	56140

Note: Teflon is a registered trademark of E.I. duPont.

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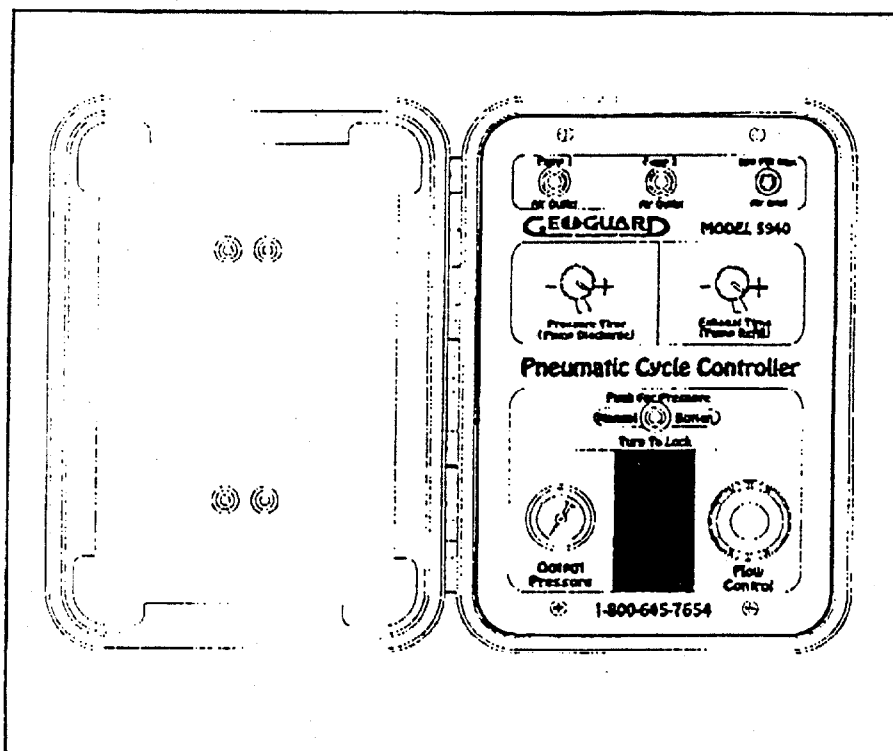
# MASTER-FLIP

Ground Water Sampling Systems

## FULLY PNEUMATIC AUTOMATIC PUMP CYCLE CONTROLLER

GEOGUARD Pump Cycle Controllers manage the compressed air used to power pneumatic pumps. They are designed with large air paths so as not to restrict the air flow as it moves from the compressed air source to the pump.

- Fine tuning, single rotation timer adjustment provides optimum pump flow rate.
- Sensitive air flow control permits high purging rates and low (less than 100ml/min.) sample rates.
- 200 psi pressure capability allows lifts up to 450 feet (135 m).
- Quick exhaust valve "short circuits" exhausting air, permits the pump to fill faster for higher purging flow rates.
- Non-corroding, quick-connect hose attachments.
- Over pressure protection.
- Liquid dampened pressure gauge.
- Manual override bypasses the timers for manual operation (used for "cold weather blow outs", packer inflation, etc.)..
- Moisture trap/air filter prevents water and particulate matter from entering controller, tubing and pump.
- Enclosed in a rugged, environmentally sealed shock resistant case.
- Doubling acting feature permits operation of two pumps. (Note: Requires additional air hose from controller to pump. Part number 50090.)



### Design Specifications

**Model#:** 5940

**Weight:** 10 lbs.

**Dimensions:** 14.5" L x 10" D x 9" W

**Timer Range:** Fill = 1 to 180 seconds. Discharge = 1 to 60 seconds. Independently adjustable.

**Pressure Capability:** 200 psi.

**Power Source:** Compressed air.

**Air Hose:** .375" I.D. reinforced, industrial air hose. Compressed air source to controller hose length is 25 ft. and includes quick-connect fittings. Controller to pump hose length is 10 ft. and includes quick-exhaust valve and quick-connect fittings. (Optional lengths available upon request).

For applications assistance call 1-800-645-7654.

**FULLY PNEUMATIC AUTOMATIC PUMP CYCLE CONTROLLER****ENGINEERING SPECIFICATIONS**

1. The Model 5940 Controller shall be housed in a gasketed case with a continuous hinged top.
2. The controller shall be fully pneumatic, powered only by compressed air.
3. The controller shall be equipped with a flow rate control capable of reducing the pump flow to less than 100 ml/min. throughout the entire lift range.
4. The controller shall incorporate a panel mounted, liquid dampened pressure gauge.
5. The controller shall incorporate separate fill and discharge timers that are independently adjustable.
6. The controller shall be capable of operating either one or two pumps. Two pump operation shall be accomplished by alternately pressurizing and venting each pump independently, from the controller panel, without the use of a manifold.
7. The controller shall be supplied with: 25 feet of 3/8" I.D., reinforced, industrial air hose with quick-connect fittings for use between the compressed air source and controller; and 10 feet of identical air hose with quick exhaust valve and quick-connect fittings for use between controller and pump tubing.
8. The controller shall be capable of cycling up to 200 psi (14 bars) without modification.
9. The controller shall be equipped with a pressure relief valve to serve as over pressure protection.
10. The controller shall be equipped with a mechanical manual override that bypasses the timers and provides for manual cycling of the compressed air.
11. The controller shall be equipped with a detachable external water trap/air filter.

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# MASTER-FL4D

Ground Water Sampling Systems

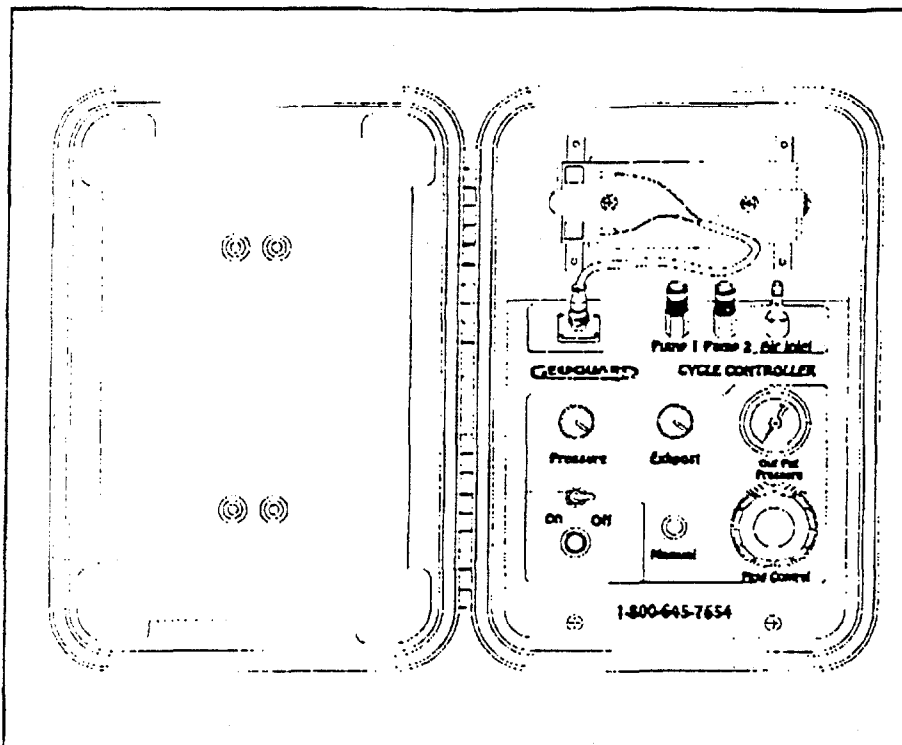
## ELECTRIC AUTOMATIC PUMP CYCLE CONTROLLER

GEOGUARD Pump Cycle Controllers manage the compressed air used to power pneumatic pumps. They are designed with large air paths so as not to restrict the air flow as it moves from the compressed air source to the pump.

- Double acting feature permits operation of two pumps simultaneously, without external manifolds. (Note: Double acting operation requires additional air hose from controller to pump. Order P.N. 50090.)
- Sensitive air flow rate control enables high rate purging, and sampling flow rates as low as a 100 ml/min.
- 200 psi pressure capability allows lifts up to 450 feet (135 m).
- Quick exhaust valve provides for rapid

pump refill even under low submergence conditions.

- Non-corroding, quick-connect hose attachments.
- Over pressure protection.
- Liquid dampened pressure gauge.
- Manual override bypasses the timers for manual operation (used for "cold weather blow outs", packer inflation, etc.).
- Moisture trap/air filter prevents water and particulate matter from entering controller, tubing and pump.
- Enclosed in a rugged, environmentally sealed, shock resistant case.



### Design Specifications

**Model#:** 5001

**Weight:** 15 lbs. (with battery)

**Dimensions:** 14.5" L x 10" D x 9" W

**Timer Range:** Fill = 1 to 45 seconds. Independently adjustable.

**Pressure Capability:** 200 psi.

**Power Source:** 12 VDC, 6 amp/hr rechargeable gel battery (battery and charger included). Provides 40 hrs. of operation between charges. 17 hr. recharge.

**Air Hose:** .375" I.D. reinforced, industrial air hose. Compressed air source to controller hose length is 25 ft. and includes quick-connect fittings. Controller to pump hose length is 10 ft. and includes quick-exhaust valve and quick-connect fittings. (Optional lengths available upon request).

For applications assistance call 1-800-645-7654.

## ENGINEERING SPECIFICATIONS

1. The Model 5001 Controller shall be housed in a gasketed case with a continuous hinged top.
2. The controller shall be powered by a 12 VDC, rechargeable gel battery of a size sufficient to power the controller for a minimum of 40 hours between charges.
3. The controller shall be equipped with a flow rate control capable of reducing the pump flow to less than 100 ml/min. throughout the entire lift range.
4. The controller shall incorporate a panel mounted, liquid dampened pressure gauge.
5. The controller shall incorporate separate fill and discharge timers that are independently adjustable. Each timer shall have a 1 to 45 second range.
6. The controller shall be capable of operating either one or two pumps. Two pump operation shall be accomplished by alternately pressurizing and venting each pump independently, from the controller panel, without the use of a manifold.
7. The controller shall be supplied with: 25 feet of 3/4 I.D., reinforced, industrial air hose with quick-connect fittings for use between the compressed source and controller; and 10 feet of identical air hose with quick exhaust valve and quick-connect fittings for use between controller and pump tubing.
8. The controller shall be capable of cycling up to 200 psi (14 bars) without modification.
9. The controller shall be equipped with a pressure relief valve to serve as over pressure protection.
10. The controller shall be equipped with a mechanical manual override that bypasses the timers and provides for manual cycling of the compressed air.
11. The controller shall be equipped with a detachable external water trap/air filter.

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## Statement of Service & Support

### Warranty

GEOGUARD's unconditional warranty covers all downwell components, including bladder pumps, tubing, and well closures, purge packers and auxiliary purge pumps for the Lifetime of the project.

All standard support equipment, including cycle controllers and compressors, is warranted for a period of one year.

### Loaner Program

In the unlikely event of controller failure in the field, upon notification, GEOGUARD will ship a loaner the same day as notified of the problem, for delivery the next day. The customer controller may then be returned to the factory for repair. Turn around time is one week, including an overnight test. The loaner controller may be retained by the customer until the repaired controller is returned.

### 24 Hour Service Hotline

GEOGUARD assures that by calling the factory 800 number, customer service assistance is always readily available. In addition to regular working hours, (Eastern time) a service technician is available via beeper, weekday after hours and weekends, 24 hours a day.

### Replacement Parts

Replacement parts such as bladders, o-rings or check balls, etc. are shipped from the factory the same day as notification of our customer service department. The local manufacturer's representative will warehouse the same items upon request. Complete listings of replacement parts are provided in the User's Manuals accompanying each system shipment.

### Field Assistance

All pumps are precleaned to meet EPA standards, sealed in polyurethane and laboratory certified to be free of contaminants. Tubing is precut to the exact length for each well as specified by the customer, attached at one end to the well closure, sealed in polyurethane and labeled with well identification. With two simple compression fitting connections, the equipment is ready to install in the well.

Each system when shipped, includes User's Manuals, providing complete instruction for installation and operation of the system. Field installation assistance by factory or local representative is readily available upon request.





**APPENDIX D**

**CTDEP GROUNDWATER RECLASSIFICATION LETTER**



# STATE OF CONNECTICUT

## DEPARTMENT OF ENVIRONMENTAL PROTECTION



### FINAL LANGUAGE AND STATEMENT OF REASONS: REVISIONS TO THE GROUND WATER CLASSIFICATIONS OF CERTAIN AREAS OF THE STATE OF CONNECTICUT

### THE SECOND HEARING IN 1996 ON RECLASSIFICATION OF GROUND WATER AS PROVIDED FOR IN GW(8)(b)(I) OF THE GROUND WATER QUALITY STANDARDS.

March 1997

On November 12, 1996 the Department of Environmental Protection, pursuant to Section 22a-426 of the Connecticut General Statutes, published notice of a hearing to consider the revision of ground water classifications in seven discreet areas of the state. These proposals were submitted to the Department as provided for in paragraph GW8(B)(i) of the Water Quality Standards of the State. A public hearing on the proposed classification changes was held on December 13, 1996 and the record was held open for the submission of additional comments until December 18, 1996.

The following is a discussion of the criteria for evaluating a proposal for reclassification, a description of the proposed reclassification areas, a summary of the hearing record and the Department's decision regarding these proposals.

#### 1) Criteria for lowering a water quality classification from GA or GAA to GB.

Standard GW(8) has several paths that can be followed by an applicant who believes that a change in classification from GA or GAA to GB is warranted. All the applications before the Department at this time have been submitted in accordance with the provisions of paragraph GW(8)(B)(i) of the Water Quality Standards. This subsection (B) and paragraph (i) have 5 criteria which must be met if a site is to qualify for lowering of the classification. These are stated as follows : *(NOTE, emphasis added)*

"(B) A ground water classification shall not be lowered to GB unless the applicant has satisfactorily demonstrated that; *(criterion 1)* any person within or down gradient of the area to be reclassified and extending to an

area previously classified as GB or to a surface water body to which the ground water discharges will be provided with an adequate public water supply, and that lowering of a ground water classification (*criteria 2*) will not prevent attainment of adjacent surface water quality goals or (*criteria 3*) present unacceptable health risks, and

(i) That the ground water to be reclassified is (*criteria 4*) polluted as a result of intense urban, commercial, or industrial development which occurred prior to 1981, and (*criteria 5*) the hydrologic conditions of the subject area are not suitable for the development of a significant public water supply..."

## 2) Summary of the applications.

The applicants proposed to lower the ground water classification in the following areas:

- 1) A 12 acre area in Derby between route 34 and Commerce street and extending down to the Naugatuck River. The area is depicted on figure 2 of exhibit 15.
- 2) In Groton, a portion of the US Naval Submarine Base extending north from the southern base boundary to high point about 1500 ft south of Long Cove and from route 12 on the east to the Thames River on the west. This area is shown on drawing 1 of exhibit 14.
- 3) In Naugatuck, an area including the Seal Products (Bunzl Art Graphics) facility at 550 Spring Street extending across a portion of the municipal golf course to Hop Brook. This area is shown on figure 7 of exhibit 9.
- 4) In New Haven, an area of 20 acres around the "Super K Mart" store southwest of the junction of Foxon Boulevard and Quinipiac Avenue, and extending west to an existing GB area. This area is shown on figure 2 of exhibit 8
- 5) In Stonington, the property of Mystic Color Laboratory and extending west to Mystic Harbor. The total area proposed for reclassification is 40 acres. This area is shown on figure number 1 of exhibit 5.

6) Wallingford. A total of eight properties located in the Barnes Industrial Park running south from Route 68, West of Barnes Road extending to the existing GB area which lies west of North Main Street. The proposed area is shown on figure 1 of exhibit 7.

7) In Wolcott an area that is south of Town Line road and extends to the Mad River on the east and Old Tannery Brook on the west and continues across the Waterbury Town Line to the confluence of the Mad River and Old Tannery Brook. This area is depicted on figure 2 of exhibit 3.

### 3) Staff Review of Applications

The staff of the Bureau of Water Management has reviewed the applications for conformity with the five criteria established in the Standards. The following is a summary of the staff findings.

*Criterion 1 (Potable Water)* In all but one of the cases, all properties within and downgradient of the proposed areas are entirely served by public water supplies drawn from outside the area. Utility maps, billing records and windshield surveys have confirmed this and local health department records have been examined to ensure that no well is present.

In the case of the application on Town Line Road in Waterbury, a single well was located within the area proposed for reclassification. This well is located on the property which is currently occupied by Mattatuck Industrial Scrap Metal Company. Exhibit 16 states that an agreement has been reached between the applicant and C&T Realty Inc., current owners of the property occupied by Mattatuck to abandon the well and provide city water to this site.

*Criterion 2 (adjacent surface water goals) and Criterion 3 (unacceptable health risks).* In all cases either investigation or remediation has been undertaken to determine the level of contamination of ground water. In the majority of cases either site remediation activities, time, or a low level of initial pollution have brought concentrations within the acceptable limits

for GB areas found in the Site Remediation Standards Regulations. In the remaining cases site remediation efforts are underway and the applicants have committed to meeting the standard for GB groundwater. In the opinion of technical staff this compliance can be achieved. All sites are in the process of being remediated or have been remediated under the cognizance of DEP staff and programs.

All sites either meet or soon will meet the acceptable standards for GB ground water contained in the Site Remediation Standards Regulations. Since the Department established those regulations to protect public health and surface water quality, the reclassification should not compromise either water quality or public health.

*Criterion 4 (site suitability for a significant well)* All of the seven sites are unsuited for the development of a significant public water supply well due to the nature of earthen and bedrock materials. Both borings and geologic mapping information is presented which indicates shallow saturated thickness, compact till soils, silts or clays are common on these sites. In two of the applications the sites are characterized by very shallow depth to bedrock.

*Criterion 5 (pollution of ground water as a result of historic development)* In all seven cases there is a considerable body of ground water monitoring information. The availability of this data is due to transfer activities, preremedial investigations and actual site remediation. In every case the ground water monitoring information indicates that substantial areas of the sites' ground water has been degraded by pollutants associated with decades of industrial or commercial activity. Pollutants that are present range from solvents to petroleum products to metals.

The staff have pointed out in their review that two of the applications include areas where no ground water contamination or historic intense development has been demonstrated. These are the application for the United States Naval Submarine Base in Groton and the Seal Products (Bunzl Art Graphics) application in Naugatuck. In both cases the applicant has extended the proposed reclassification area to provide a recognizable boundary and to ensure that no new potable water supply wells that could

induce a flow of contaminated water are installed.

In the case of the Naval Base the northern boundary of the reclassification area is described by a ridge line or series of hilltops running from Route 12 westerly, proximate to the Thames River. This includes a substantial area bounded by route 12 to the east, Perimeter Road to the south and the proposed boundary to the north. There is no evidence that any contamination has taken place in this upgradient woodland area. Therefore, it is appropriate that the northern boundary of the reclassification area should be altered as follows: the boundary as proposed by the applicant from the Thames River proceeding easterly to the junction with Perimeter Road, then following the Perimeter Road until the road turns south to parallel Route 12, at which point the boundary shall run to the east and intersect Route 12.

With regard to the application of Seal Products (Bunzl Art Products) a model has been submitted that demonstrates a probable plume flow leaving the subject property and moving west south west and downgradient across a municipal golf course until it discharges at Hop Brook. The applicant has submitted correspondence as evidence that Naugatuck has no objection to the proposed reclassification of ground water under its municipal golf course.

Staff have questioned why the area of the golf course proposed for reclassification is greater than the modeled plume area. In this case the proposed reclassification area is drawn to the minimum area that can readily be observed on the ground and on maps. The boundaries are the property lines to the east, a gas line right-of-way to the south and Hop Brook to the west. There does not seem to be a practicable smaller area for depiction. Therefore, the proposed reclassification area is appropriate.

Each application documents industrial or commercial uses on these sites which predates the adoption of the first ground water quality standards in 1981. In all cases contamination of the ground water based on historic practice has been documented.

Based on the review, and with the exception of the northern boundary of the Naval

Submarine Base (as noted), the staff has concluded that all seven sites meet the 5 tests for lowering of the ground water classification.

**Oral and written testimony**

A very limited amount of testimony (excepting the applications) was received in this proceeding.

Mr. John Hankins, from Fuss & O'Neill, representing Mystic Color Laboratory testified that an inappropriate method of remediation was proposed in the engineering report and that other methodologies would be used on that site. This does not alter the basis of the application.

Attorney Austin Carey Jr. representing Buell Industries, owners of property immediately upgradient of the area in Wolcott/Waterbury proposed for reclassification presented both written and oral testimony. The principal concern he expressed was that if this proceeding required that the Department rule that Old Tannery Brook is a hydrogeologic divide, then that decision be deferred until an ongoing study of the area by the United States Geologic Survey is completed. Providing the Department had no need to rule on that issue, Buell Industries had no objection to the reclassification.

Attorney Gregory Sharp, representing the "former Buell shareholders" who have filed the subject reclassification request points out that there is no need for the Commissioner to make a decision on the status of Old Tannery Brook. If the Brook was a hydrologic boundary the site would meet the five tests. If the Brook is not a hydrologic boundary then any groundwater crossing the "brook" would enter a longstanding GB ground water area. The issue of the Brook is then immaterial in the matter before the Department and the staff recommends no action or ruling on that issue.

At the request of Attorney Sharp the record was held open until the close of business on Wednesday, December 18 to allow the submission of additional written testimony. The only document submitted during this extension is exhibit 16, a letter from Attorney Sharp confirming that agreement had been reached with C&T Realty to abandon the existing well and provide public water to the site occupied by Mattatuck Industrial Scrap Metal, Inc.

The Department has received the following letters (exclusive of those contained in the applications) concerning this matter:

1) Exhibit 17. A letter from Mr. Bill Bures of Shelton requesting that the Department not consider the three requests for lowering groundwater in areas that are tributary to the Naugatuck River. Mr. Bures believes that such actions will lower the quality of the river itself.

Discussion: The proposal before us does not allow any additional discharges the surface or ground water. There is no authorization now or in the future for this process to lead to an increase in wastewater discharge or pollution. The issue is the classification of the groundwater and the purpose of this effort is to facilitate the cleanup of past pollution and the productive reuse of these sites.


Approval of these applications will alter and lower the goal for ground water from suitable for drinking without treatment to a classification that is accurate and appropriate for these urban and industrial areas.

2) Exhibit 2. Attorney Carey has requested that the decision in this matter be mailed to him. That will be done.

### Final Decision

Based on the record before me I hereby grant the 7 requests for reclassification which are the subject of these proceedings. The application for the United States Naval Submarine Base shall be granted with the condition that the northern boundary of the area to be reclassified is modified in the manner recommended by the staff. The Wolcott/Waterbury, Town Line Road reclassification shall take effect when it is confirmed that the one downgradient well utilized by Mattatuck Industrial Scrap Iron Incorporated has been abandoned and that facility connected to public water. These changes will be incorporated in the Water Quality Classifications maps as new editions are prepared.



  
Sidney J. Holbrook, Commissioner

8

March 5, 1997

Date

**List of Speakers at the Public Hearing**

Mr. John Hankins  
Mr. Austin Carey Jr.  
Mr. Greg Sharp

**List of Exhibits**

- 1) Letter from Austin Carey Jr. to the H.O. dated 12/12/96, commenting on Wolcott application.
- 2) Letter from Austin Carey Jr. to the H.O. dated 12/12/96, requesting notice of decision.
- 3) Application filed by Murtha, Cullina, Richter & Pinney for the Wolcott/Waterbury application, dated 10/24/96.
- 4) Supplement to the application filed as exhibit 3, dated 11/24/96.
- 5) Application Package, Mystic Color Laboratory, submitted by Fuss & O'Neill Inc, dated June 28, 1996.
- 6) Letter Peter DiBasi, director Mystic Community Center to H.O. dated 9/9/96
- 7) Application filed by Murtha, Cullina, Richter & Pinney for Coastcast, dated 9/18/96.
- 8) Application filed by Haley & Aldrich, for New Haven Super K-Mart, 10/16/96.
- 9) Application of Seal Products, (Bunzel Art Graphics, Naugatuck) dated 10/23/96.
- 10) Letter from Gregory Sharp to town planner, Naugatuck, 11/8/96
- 11) Letter from Gregory Sharp to H.O., 11/18/96
- 12) Memorandum from Maurice Hamel to H.O., 11/29/96.
- 13) Letter from Gregory Sharp to H.O., 12/2/96.
- 14) Application of U.S. Navy, 8/2/96.
- 15) Application filed by Cody Ehlers Group for Petro Plus Inc. 10/17/96.
- 16) Letter from Gregory Sharp to H.O., 12/16/96
- 17) Letter from Bill Bures to DEP, stamped "Received Nov. 19, 1996"
- 18) Authorization to hold hearing, 10/31/96
- 19) Notice as it appeared in Law Journal and Newspapers.

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- 20) Copies of letters to CEO's
- 21) Return receipts from CEO's
- 22) Requests for and affidavits of publication

**APPENDIX E**  
**ANALYTICAL DETECTION LIMITS**

TABLE E-1

**ANALYTICAL DETECTION LIMITS  
GROUNDWATER MONITORING PLAN  
DRMO-NSB-NLON, GROTON, CONNECTICUT**

Chemical	Lowest Groundwater Criterion(1)	Lowest Surface Water Criterion(2)	Reporting Limit(3)	Analytical Method
<b>VOCs (µg/L)</b>				
1,1,2,2-Tetrachloroethane	100	11	1	OLC02.0, CLP - low level
1,2-Dichloroethane	90	99	1	OLC02.0, CLP - low level
1,2-Dichloroethene (total)	NA	NA	1	OLC02.0, CLP - low level
Trichloroethene	540	81	1	OLC02.0, CLP - low level
Vinyl Chloride	2	525	1	OLC02.0, CLP - low level
<b>SVOCs (µg/L)</b>				
Benzo(a)anthracene	0.3	0.031	0.13	SW-846, 8310 HPLC
Benzo(a)pyrene	0.3	0.031	0.23	SW-846, 8310 HPLC
Benzo(b)fluoranthene	0.3	0.031	0.18	SW-846, 8310 HPLC
Benzo(k)fluoranthene	0.3	0.031	0.17	SW-846, 8310 HPLC
Benzoic Acid	NA	NA	50	SW-846, 8270B
Bis(2-ethylhexyl)phthalate	59	5.9	5	SW-846, 8270B
Fluoranthene	3,700	370	2.1	SW-846, 8310 HPLC
Fluorene	140,000	14,000	2.1	SW-846, 8310 HPLC
Naphthalene	NA	NA	18	SW-846, 8310 HPLC
Phenanthrene	0.077	0.031	6.4	SW-846, 8310 HPLC
Pyrene	110,000	11,000	2.7	SW-846, 8310 HPLC
<b>Pesticides/PCBs (µg/L)</b>				
Heptachlor Epoxide	0.05	0.00011	0.01	OLC02.0, CLP - low level
Aroclors 1254 & 1260	0.5	0.000045	0.20	OLC02.0, CLP - low level
2,3,3',4,5,6-Hexachloro-1,1'-biphenyl	0.5	0.000045	(4)	OLC02.0, CLP - low level
4,4'-DDD	NA	0.00084	0.02	OLC02.0, CLP - low level
<b>Inorganics (µg/L)</b>				
Arsenic	4	0.14	10	CLP ILM04.0, trace ICP
Barium	NA	NA	200	CLP ILM04.0, trace ICP
Cadmium	6	9.3	5	CLP ILM04.0, trace ICP
Chromium	21.5	50	10	CLP ILM04.0, trace ICP
Copper	25.6	2.4	25	CLP ILM04.0, trace ICP
Lead	13	8.1	3	CLP ILM04.0, trace ICP
Silver	12	1.9	10	CLP ILM04.0, trace ICP
Zinc	31.3	81	20	CLP ILM04.0, trace ICP

Shading denotes monitoring criterion lower than practicable reporting limit

NA: Not Applicable

- Connecticut's standard Surface Water Protection Criteria (SWPCs). Site-specific SWPCs are 10 times higher
- Federal Ambient Water Quality Criteria (AWQCs) for the protection of human health for consumption of organisms, except for cadmium, chromium, copper, lead, silver, and zinc which are the Federal salt water AWQCs for protection of aquatic life
- Practical Quantitation Limits (PQLs) are provided for SW-846 analyses. PQLs may vary, based on the laboratory selected. Contract Required Quantitation Limits (CRQLs) are provided for CLP organic analyses. Contract Required Detection Limits (CRDLs) are provided for CLP method analyses. **It should be noted that the laboratory will report to its Instrument Detection Limit (IDL) for inorganics. The IDLs should actually be lower than the CRDLs for inorganics.**
- Analysis for this compound is very uncommon; therefore, no information about reporting limits is available. The lab will be required to add this compound to the pesticide/PCB analyte list.